

# NUTS AND VOLTS

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APRIL 2006

EVERYTHING FOR ELECTRONICS

## THE PROPELLER

Putting a New  
Spin on  
Embedded  
Control



■ **ZEN AND THE  
ART OF ZIGBEE**

■ **BUILD THE THEREPING**

■ **SHORT-RANGE  
NETWORKING**

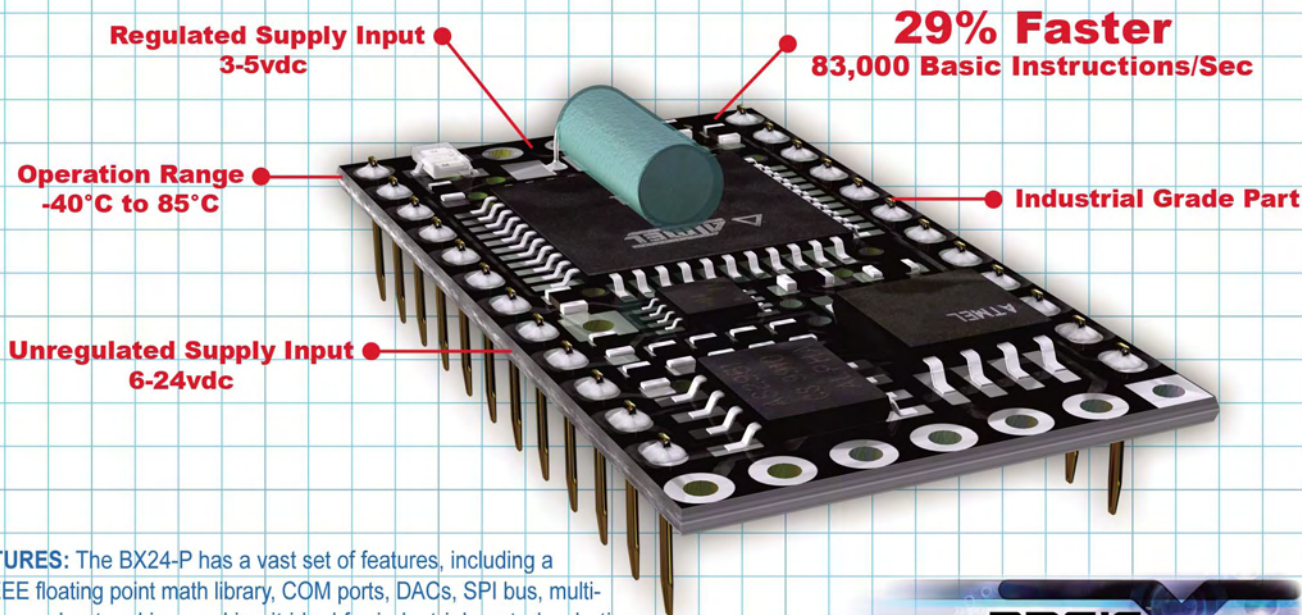
■ **CONSTANT  
CURRENT SOURCES**



# Announcing the BasicX - BX24-P

The *fastest* Basic programmable microcontroller...

**Just Got BETTER for the same price \$49.95**



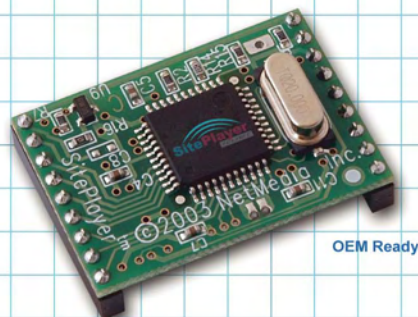
**FEATURES:** The BX24-P has a vast set of features, including a full IEEE floating point math library, COM ports, DACs, SPI bus, multi-tasking and networking, making it ideal for industrial control, robotics, automated testing equipment and home automation. BX24-P is able to monitor and control all your switches, timers, motors, sensors, relays, and more. Measuring just 1.25" X .75", OEMs can easily see the value of this little powerhouse.



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## Announcing SitePlayer Telnet™ Serial to Ethernet Data Converter

**SPT1 – SitePlayer Telnet™ OEM module**  
**ONLY \$29.95**

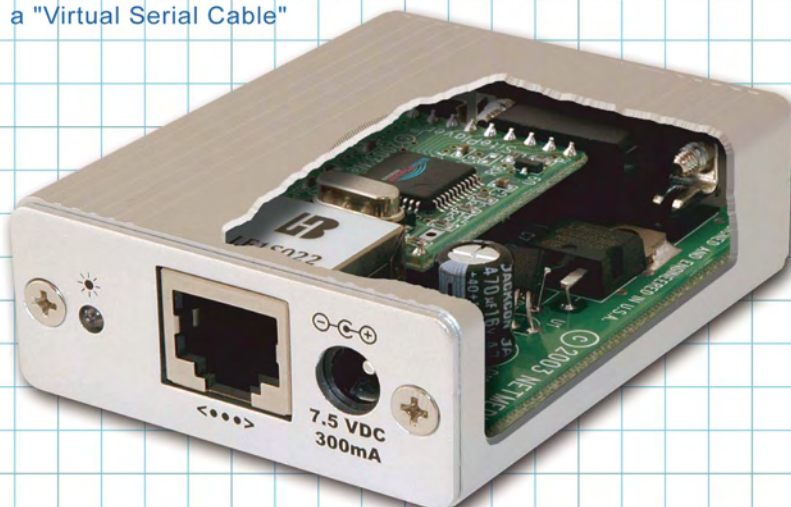


**Features -** 10BaseT, ARP, UDP, TCP/IP, DHCP, Link Local, Bonjour, ICMP Ping, HTTP, Telnet, Daytime protocol, Discard protocol, 4 IP addresses, Serial AT command mode for external processor control of Ethernet sessions.

Enable your serial devices to communicate across Ethernet

The SitePlayer Telnet module gives OEM's and product designers the ability to quickly and cost-effectively bring their products to market

Two SitePlayer Telnet systems can easily be configured to create a "Virtual Serial Cable"



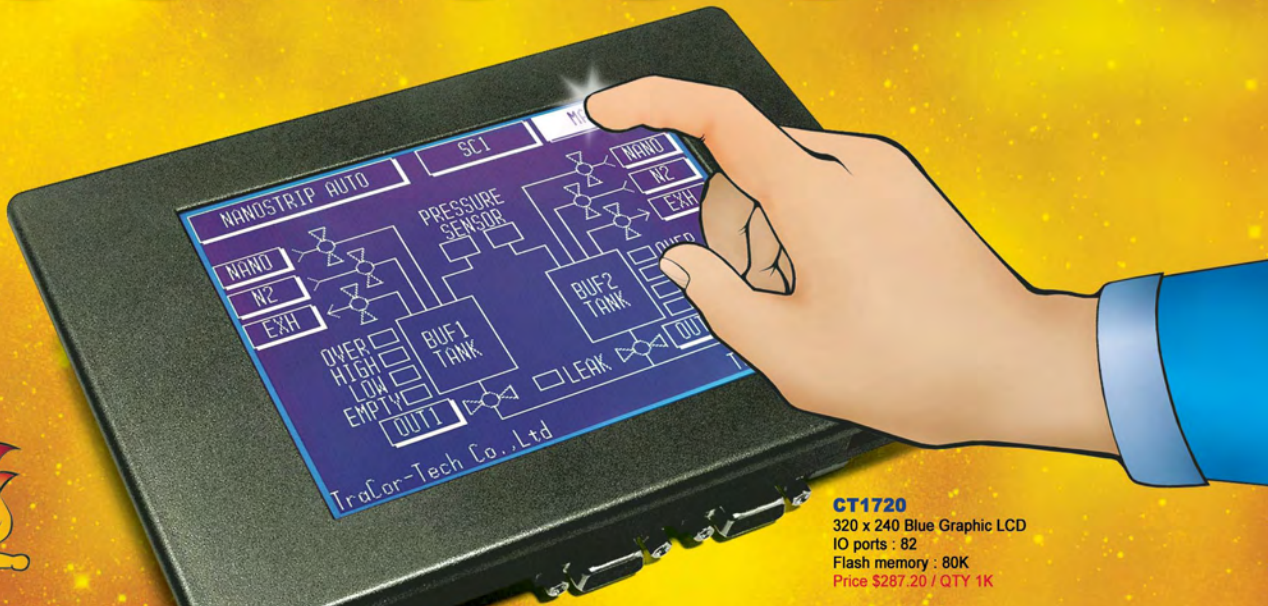
**SPTS – SitePlayer Telnet™ System, now available directly from NetMedia at an Introductory price of \$79.95**





ALL-IN-ONE Type Touch Panel Controller

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Flash memory : 80K  
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Data memory : 28K  
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### BASE BOARD

#### CuBASE-32M

Input/Output circuit for CB280  
24V Input (Photocoupler) : 16  
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AD Input Circuit : 6  
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RS232 Communication  
LED backlight  
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#### CB280

CUBLOC CORE MODULE  
IO ports : 49  
Flash memory : 80K  
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#### CSG-4S

4 digit small type 7 segment display  
Price \$19.00 / Each



#### CB220

CUBLOC CORE MODULE  
IO ports : 16  
Flash memory : 80K  
Price \$27.20 / Qty 1K



#### CuBASE-64M

Input/Output circuit for CB290  
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NPN Transistor Output : 32  
AD Input Circuit : 8  
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High Counter : 2  
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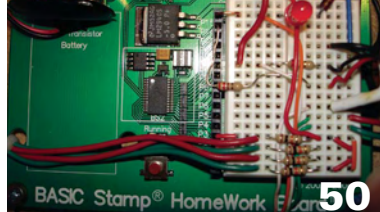
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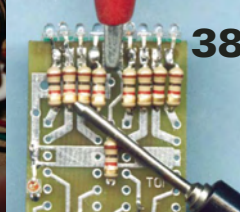




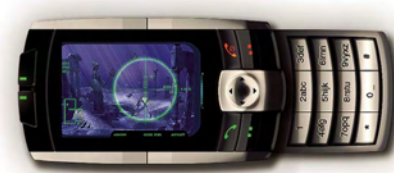
68



50



38



8

# NUTS AND VOLTS

APRIL 2006

## PROJECTS and FEATURES

### 38 OCTAL LOGIC PROBE

Plug this device directly into a prototyping socket to view eight adjacent pins at the same time.

■ By Jim Brannan

### 44 BUILD THE POCKET MARQUEE BADGE

Put your name in lights with this eye-catching pin.

■ By Doug Malone

### 50 THE CREATION OF THE THEREPING

No musical skills are required to play *this* digital instrument.

■ By Vern Graner

### 60 VIDEO DIGITIZER CHOICES

"Edited version" to cut through marketing trivia to find out the best choices for your video editing needs.

■ By Brian Mork

### 68 CONSTANT CURRENT SOURCES — PART 1

This very applications-oriented tutorial first defines a constant current source, then shows what it can do for you.

■ By Vaughn D. Martin

## ON THE COVER ...

The new Propeller by Parallax is more than a microcontroller — it's a *multi*-controller. Check out this month's Stamp column for all the details.



## COLUMNS

- 08 TECKNOWLEDGEY 2006**  
Events, advances, and news from the electronics world.
- 12 OPEN COMMUNICATION**  
Short-range networking.
- 16 STAMP APPLICATIONS**  
A new spin on embedded control.
- 24 Q&A**  
Digital wind vane, USB power booster, vacuum tube power amps, and more.
- 74 GETTING STARTED WITH PICs**  
Going beyond 31 commands.
- 80 PERSONAL ROBOTICS**  
Zen and the art of Zigbee.
- 86 THE DESIGN CYCLE**  
Arm yourself with Philips microcontrollers.

## DEPARTMENTS

- 06 READER FEEDBACK**
- 34 NEW PRODUCTS**
- 36 SHOWCASE**
- 67 ELECTRO-NET**
- 96 CLASSIFIEDS**
- 99 NEWS BYTES**
- 100 NV BOOKSTORE**
- 102 TECH FORUM**
- 105 ADVERTISERS INDEX**

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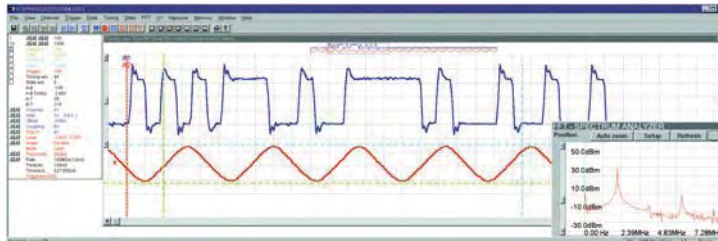
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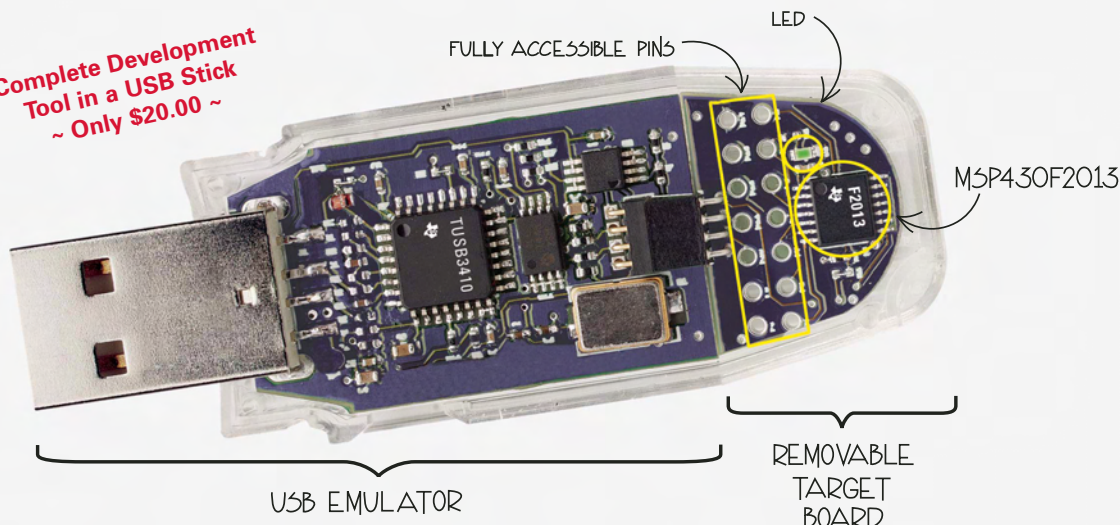


## 6 NUTS AND VOLTS March 2006



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It's easy to rev up your application in minutes with the new **eZ430-F2013**, the world's smallest complete development tool for only **\$20!** The tool provides all hardware and software needed to evaluate the MSP430 or complete an entire F20xx project. The F20xx combines 16 MIPS performance, less than 1 microamp standby current, with your choice of analog converters - from a comparator, fast 10-bit ADC to 16-bit sigma-delta with integrated PGA - all in a package as tiny as 4x4 mm.

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MSP430F2012	2 KB	128 B	✓	10-bit ADC	\$1.15
MSP430F2003	1 KB	128 B	✓	16-bit ADC	\$1.50
MSP430F2013	2 KB	128 B	✓	16-bit ADC	\$1.65



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■ BY JEFF ECKERT

## ADVANCED TECHNOLOGY

### NEUTRON SOURCE NEARS COMPLETION

IMAGE BY LYNN FREENEY, COURTESY OF DEPARTMENT OF ENERGY



■ Samuel McKenzie examines a ring half cell quadrupole magnet that the Spallation Neutron Source (SNS) received from Brookhaven Lab.

It's been under construction since 1999 and will end up costing \$1.4 billion, but it looks like the Department of Energy's spallation neutron source (SNS) will be completed by the end of this year. The last major milestone — the commissioning of the proton accumulator ring — was accomplished in February.

Located at the DoE's Oak Ridge National Laboratory (ORNL), the SNS uses a superconducting linac (short for "linear accelerator") to produce proton pulses that travel at nearly 90 percent of the speed of light. In the ring, the protons within a pulse are "accumulated" to increase the intensity 1,000-fold.

At that point, this now very intense pulse is extracted and delivered to the mercury target to produce neutrons. This happens 60 times per second (which could produce some nasty 60-cycle hum). The protons are aimed at a mercury target that, when struck by them, gives off ("spalls") neutrons. After only three days of its initial operation, the ring accumulated protons, which were then extracted and sent to a point just short of the target.

Because of their lack of charge,

neutrons are exceptionally good at penetrating materials. Researchers can determine a material's molecular structure by analyzing the way the neutrons scatter after striking atoms within a target material. SNS will direct the spalled neutrons to a range of sophisticated instruments.

According to ORNL, the SNS will be the world's highest intensity proton accelerator, offering an order of magnitude more beam power than any other facility. The SNS is expected to become the world's leading research facility for studying the structure and dynamics of materials using neutrons. It will enable researchers from the United States and abroad to study the science of materials that forms the basis for new technologies in telecommunications, manufacturing, transportation, information technology, biotechnology and health. For details, more photos, and videos, visit [www.sns.gov](http://www.sns.gov)

### DEVICE WILL SENSE THROUGH CONCRETE WALLS

The Defense Advanced Research Projects Agency (DARPA; [www.darpa.mil](http://www.darpa.mil)) has come up with a portable "Radar Scope" that will sense the presence of a human being inside a building, even through one foot of concrete and 50 feet beyond. Primarily designed to provide protection for troops conducting door-to-door operations in urban areas, the user simply places it against a wall, and it can detect movements as minor as someone breathing.

According to DARPA, even though it weighs only 1.5 lbs., the

■ DARPA expects its portable Radar Scope — which will look similar to this prototype — to be in the field as soon as this spring.

device provides far better sensory capability than commercially available motion detectors. Amazingly enough, it will cost only about \$1,000, making it on par with what the military pays for hammers and toilet seats. The Radar Scope is waterproof and ruggedized, and it runs on standard AA batteries.

Even as the organization hastens to make the devices available to combat forces, DARPA is making plans that build on the technology. One proposed expansion is called "Visi Building," which will actually "see" through multiple walls, penetrating entire buildings to show floor plans, locations of occupants, and placement of materials such as weapon's caches.

While this is expected to take a few more years of development, troops will be able to use it simply by driving or flying by the structure under surveillance. One can, of course, envision some unpleasant applications of the technology should it become available to your local police department or even professional burglars. But it will obviously save some lives on the battlefield.

## COMPUTERS AND NETWORKING

### SOFTWARE OFFERS CONTINUOUS DATA PROTECTION

For Windows® users who face the threat of worms, viruses, spyware,



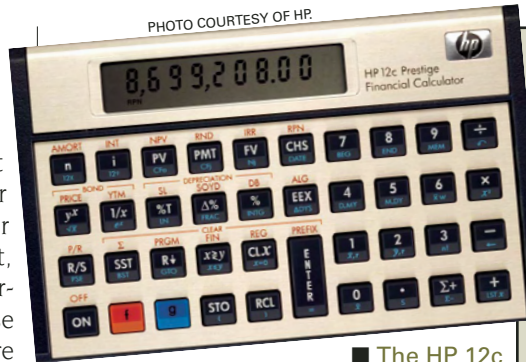


and other attacks to desktop and mobile PCs (which is to say, all of them), Phoenix Technologies, Ltd. ([www.phoenix.com](http://www.phoenix.com)), now offers Recover Pro, an application that enables full PC restoration in a matter of minutes, without the need for intervention by the IT department, network connection, or the use of external recovery media. With a few mouse clicks, end users can selectively restore a deleted file, recover a previous version of a file, or completely restore the hard drive to its precrash state, including the operating system, applications, user settings, and data files. Recovery time is said to be only three to five minutes.

Recover Pro is a self-contained application housed in a protected portion of the hard drive. It provides a higher level of security because the software works even when Windows won't boot. Recovery data is stored in a hidden partition on the hard drive and is not vulnerable to attacks on the operating system. The recovery process can be accessed from a Windows interface or via the F4 hot key when Windows won't boot. The product is designed for Windows XP and 2000 environments and runs on Pentium III and newer processors. The reported list price is \$49.95.

## UPDATED LAYOUT PROGRAM INTRODUCED

The DipTrace layout software from Novarm ([www.diptrace.com](http://www.diptrace.com)) is designed for both PCB professionals and hobbyists, with the goal of "provid-



■ The HP 12c Prestige calculator turns 25 this year.

ing affordable solutions for electronic designers, including CNC applications, that are both powerful and easy to use." The package includes components for PCB layout, schematic capture, a pattern editor (to create part footprints), and a component editor (allows you to draw parts and make components).

The company emphasizes its intuitive user interface and simple operation. For example, a schematic can be converted to a PCB with one mouse click. The board designer can instantly modify the PCB from an updated schematic while maintaining existing placement, routed traces, board outline, mounting holes, and other work.

DipTrace has an automatic router that can route single-layer (bottom side) and multilayer circuit boards, and there is an option to autoroute a single-layer board with jumper wires. Smart manual routing tools allow users to finalize the design.

The program supports different output formats, including DXF, N/C drill files for numerically controlled drilling machines, and the Gerber files that most board manufacturers use. The important feature for hobbyists is automatic creation of isolation poly lines and the ability to export them to DXF files, which can be converted to G-

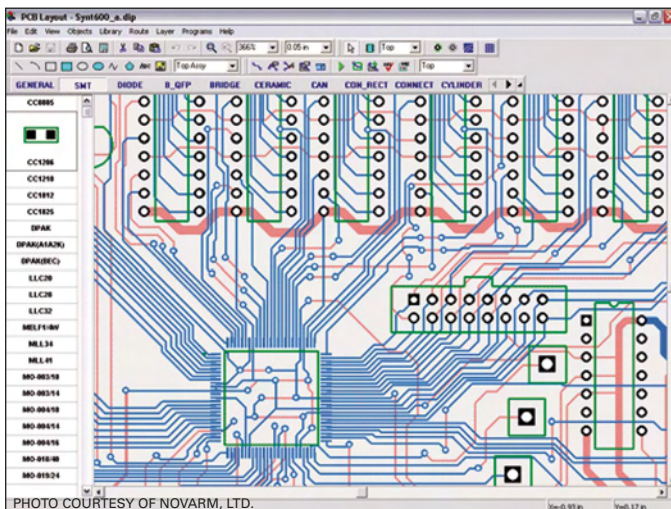


PHOTO COURTESY OF NOVARM, LTD.

■ The DipTrace PCB layout program allows the design of circuit boards using automatic and manual routing.

## INDUSTRY AND THE PROFESSION HEWLETT-PACKARD CONDUCTS CONTEST

If you own an HP 12c calculator and act fast, you may be able to win one of the prizes HP is awarding to winners of its "The Tales of the Amazing HP 12c Calculator Contest," which runs through May 1 and is open to US residents who own or have owned the classic device. Prizes include an HP Pavilion LC3700N 37-in LCD HDTV (suggested retail price of \$2,700), as well as desk clocks and embroidered caps commemorating the calculator's 25th anniversary.

To enter the contest, all you have to do is submit your own amazing tale in 150 words or less. Winners will be determined by the compelling nature of the entry essay.

Topics can be as varied as how the HP 12c Calculator helped people sell their first house or how it helped them land their first job. First introduced in 1981, the HP 12c has become an industry standard in the business and finance community with millions sold over the years. With the exception of improved performance due to modern components, the HP 12c sold today acts and looks just like it did when it made its worldwide debut. For complete contest rules, visit [www.hp.com/go/12cAnniversary](http://www.hp.com/go/12cAnniversary)

## MONKEYS CALLING

This month's award for the strangest new service goes to BinFone Telecom ([www.binfone.com](http://www.binfone.com)), which now offers a wake-up and call reminder service. That's not so unusual, but the twist is that subscribers receive the calls from monkeys that "happily screech, howl, and whoop it up when the sleepy consumer answers the phone in the morning." And you can even hit a snooze button on the phone if you need a few more minutes of sleep.

The service and website both go by the name of **MorningMonkeys.com**. You can sign up for single calls, as well as packages of 5, 10, or 30 calls per month, and a two-week free trial is offered. Details are available online.



code with the free ACE Converter tool.

DipTrace also exports G-code for drilling directly to Mach2/3 software. DipTrace contains a 50,000+ component library and comes in several versions. The unlimited version is priced at \$595, but you can also get one that is limited to 1,000 pins for \$345, and DipTrace Lite (limited to 500 pins) for \$145. Best of all for many of us, there is free version available for students and hobbyists with a 250-pin limit.

## INTEL MOVES TO SUPPORT APPLE DEVELOPERS

If anyone doubted Intel's eagerness to support the new Macintosh models that use its processors, that doubt should be fading. Recently, the company announced new software development tools for the Mac platforms, and they are available through its Intel® Software Network.

The new tools and resources will help Apple developers take advantage of Intel Core™ Duo processor technologies to maximize application performance. The special beta versions of the Intel® Fortran Compiler, Intel® C++ Compiler, Intel® Math Kernel Library, and Intel® Integrated Performance Primitives are available now. The tools are integrated into

Apple's Xcode development environment and offer an alternative to existing tools and compilers. Intel will also provide other resources to assist with software optimization, dual-core threading, and migration information. More information is available at [www.intel.com/software/apple](http://www.intel.com/software/apple)

## CIRCUITS AND DEVICES

### SUPERCAPACITOR PROMISES MORE POWER

OptiXtal, Inc., has announced the development of a new class of stackable supercapacitors for transport and other applications. Dubbed SuperXCaps™, the devices are said to be more powerful than other supercapacitors, because their extremely lightweight design enables them to deliver more watts per kilogram of weight.

Unlike bulky cylindrical capacitor designs, the sealed flexible film package developed by the company's research team has the conformal shape quality to give engineers wider design flexibility. Apparently, they can be bent around a radius or

stacked one on top of the other to produce nearly any desirable shape and electrical configuration — series, parallel, or any combination to achieve the desired power delivery requirements.

According to OptiXtal, laboratory tests have shown that the new devices are nearly 250 percent lighter and capable of delivering equal power, in terms of W/kg, as compared to existing products. They are said to charge to full capacity quickly, show negligible voltage losses over long periods of time, and offer reliability for hundreds of thousands of charging cycles.

The drawback is that they are not currently in mass production, but OptiXtal, Inc., is seeking serious investors to help bring them to market. If you have a bulky wallet and want to get in on the ground floor, feel free to contact the president himself, Dr. Sagar Venkateswaran. You can find his mailing address at [optixtal.com](http://optixtal.com)

### IMPROVED GRAPHICS FOR MOBILE DEVICES



PHOTO COURTESY OF BITBOYS.

■ New processors improve graphic interfaces for mobile devices.

If you're looking forward to playing games and watching videos on your cell phone, watch for the employment of Bitboys ([www.bitboys.com](http://www.bitboys.com)) graphics hardware in the

next generation of mobile devices. Introduced a few weeks ago are two processors: the G12, billed as the world's only vector graphics processor for mobile and embedded environments, and the G40, a 2-D/3-D vector processor for volume-market multimedia phones and smart phone platforms.

According to the company, the devices stand to dramatically improve the graphics capability of mobile phones. Applications include enhanced user interfaces that are easier and more intuitive, next-generation mobile games, maps and navigation, web browsing, and entertaining graphics content that will drive consumer demand for more sophisticated wireless devices. **NV**

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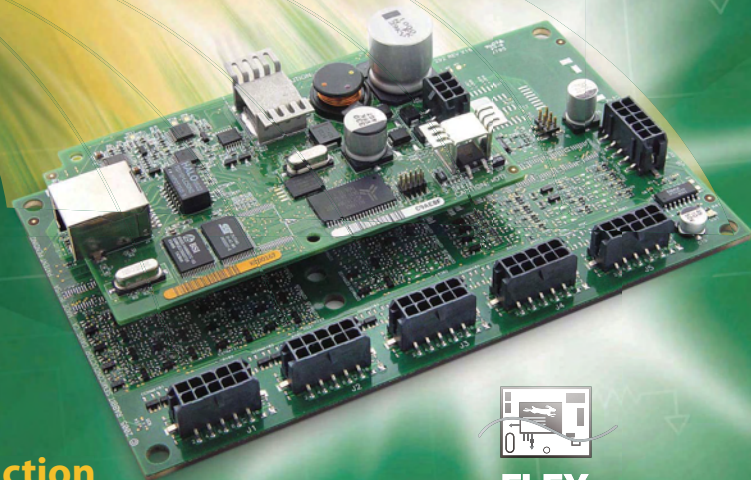
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■ BY LOUIS E. FRENZEL

## SHORT-RANGE NETWORKING

### The I<sup>2</sup>C and SPI Buses

**MOST OF US THINK OF LONG-RANGE communications when we think of communications applications. Long-range is subject to interpretation, but is usually many meters to many miles. Short-range communications is typically 10 meters or less. We use short-range wireless devices virtually every day; some examples being our infrared remote controls, remote keyless auto entry, garage door openers, Bluetooth headsets on cell phones, and wireless thermometers. But short-range wired communications are not that familiar to most people even though they are more common than you probably know.**

As ICs have gotten larger, more complex, and higher in speed, they are increasingly more difficult to connect to one another. The same for connecting multiple PC boards in larger products. Multiwire cables just don't work well beyond several feet and are almost worthless for high speed parallel buses which are good for up to a few inches and they require complex and expensive connectors.

The result has been the creation of a bunch of simple serial data buses that transmit not only data, but also monitor and control signals between PC boards and between ICs on a PC board. Rather than try to run 16 and 32 bit buses and dozens of control lines between boards and ICs, you can use two or three lines making up a serial data bus that simplifies the transfer of desired data and

control information. Bottom line, using serial buses greatly reduces data and control pin counts on ICs which is a huge factor in design, manufacturing, testing, and cost.

There are a half dozen or more such serial buses now in use. Probably the two most common are the I<sup>2</sup>C and SPI buses. They are the subject of this month's column.

### THE I<sup>2</sup>C BUS

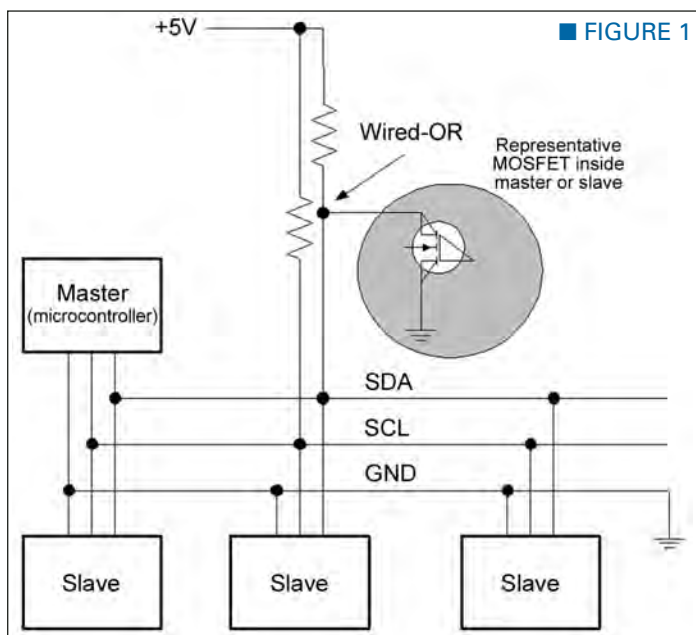
The I<sup>2</sup>C bus was invented by Dutch electronics giant Philips in the 1980s as a way to interface an embedded controller to a tuner and other devices in a modern TV set. I<sup>2</sup>C stands for Inter-Integrated Circuit bus and is usually pronounced I squared C. It is a two-wire (plus ground) serial bidirectional bus that interconnects ICs or other circuits designed to use it.

Figure 1 shows the general configuration. The two primary lines are the serial data line (SDA) and the clock line (SCL). Both are referenced to a common ground. These lines are typically just copper paths on a PC board between ICs, but it can also be short segments of twisted pair cable.

The SDA and SCL lines are of the open drain type (open collector for those of you who still haven't accepted MOSFETs as the dominant transistor type) that uses a pull-up resistor to +5 volts. All of the interconnected circuits share the common bus lines. The MOSFET in Figure 1 is an example of what is on the bus inside the master and slave circuitry.

Any device may transmit or receive data in either direction, but only one device can speak at a time. When the SDA is not transmitting data, it normally sits high at +5 volts. Any MOSFET drain on the bus can then pull the line low. Pull-up resistor values run from 1.8K to about 10K — the lower the value, the faster the data rate.

The data rate can be any thing from zero up to 100 kbps. The pull-up value depends on how many connected



■ FIGURE 1

loads there are. Each contributes some capacitance on the line that must be charged so the lower the pull-up value, the faster the rise time and the greater the data rate. And don't forget that the longer the bus lines, PC board copper, or cable, the greater the capacitance to charge, so lower pull-ups will give better performance. While the I<sup>2</sup>C system can accommodate up to 128 parallel devices on the line, rarely is even a fraction of this capacity used.

While most I<sup>2</sup>C systems run at low speed from 10 kbps to 100 kbps, there are faster versions available to run at 400 kbps up to 3.4 Mbps. These are typically used over shorter distances.

As Figure 1 shows, the I<sup>2</sup>C bus devices are usually designated as either a master or slave. The master provides overall control of transmissions and supplies the clock to the slave devices. Only a master can initiate a data transfer. Slaves simply respond to read or write commands from the master. The master can be an IC designed for the purpose or, in most cases, it is actually built into an embedded controller. Many single chip microcontrollers include an I<sup>2</sup>C bus as a standard I/O port. The slave devices are usually other ICs designed to be set up and controlled over this bus.

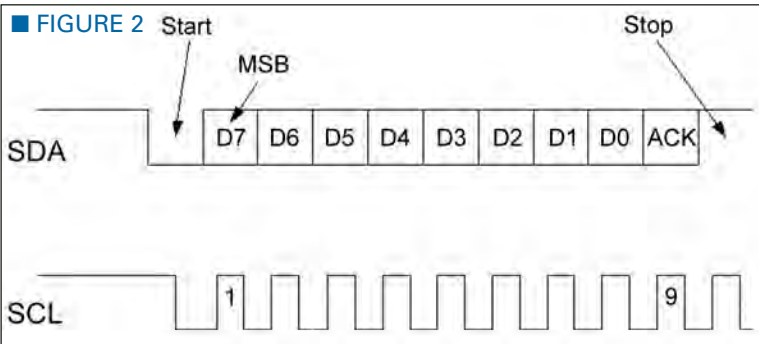
The I<sup>2</sup>C bus has a transmission protocol like all other networking methods. It is a synchronous bus meaning that the bit transfer is controlled by the clock. But it is also asynchronous since it can start and stop at any time as initiated by the master. It uses start and stop bits somewhat like those used in standard RS-232 UART serial port communications.

The SDA line stays high until a one bit long binary 0 (low) bit occurs. The SCL line goes low shortly thereafter, and the clock causes the serial data to be transferred. A stop sequence occurs when the SCL line goes high and stays high for a one bit period, then the SDA line rises back to the binary 1 or high condition.

Data is designed to be transmitted in eight-bit bytes. These are accompanied by some control bits that determine what happens. Figure 2 shows the protocol. The data bit D7 is the MSB and is transmitted first. A ninth bit designated ACK follows the data bits. The ACK bit is transmitted by the receiving slave device to acknowledge the receipt of the data and this indicates it is ready for another transfer.

The first transmission is usually the address that identifies the slave to be involved in a read or write operation. The format is shown in Figure 3. The address is seven bits long, giving a maximum of  $2^7 = 128$  possible slave devices. Address bit A6 is the MSB and is transmitted first. The I<sup>2</sup>C system includes a 10-bit addressing option but rarely is it ever used. The eighth bit transmitted is a read or write (R/W) bit that tells if the master is requesting the slave to be read from (binary 1) or written to (binary 0). The ninth bit is the ACK bit as described before.

After the address is transmitted, the protocol usually calls for sending a code identifying a register in the slave that is to be read or written to. Some slave ICs have multiple registers that are either monitored by the master or written to. After the register number is sent, the data transfer is initiated. Then the sequence ends.



Most I<sup>2</sup>C procedures are programmed as part of the embedded controller code in the product. Micros incorporating this bus have instructions and software to handle the I<sup>2</sup>C functions.

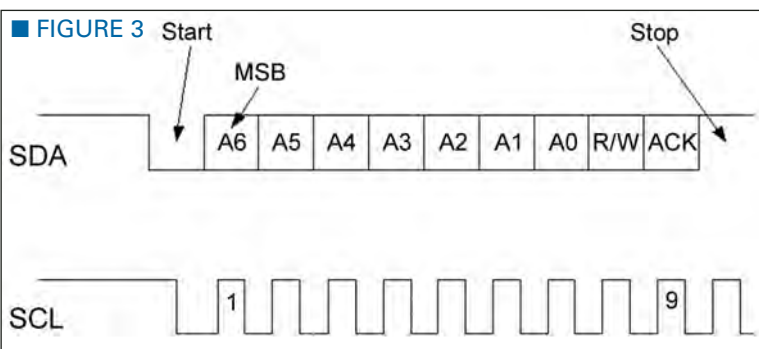
## I<sup>2</sup>C APPS

As you can imagine, with such a simple and flexible protocol you can control and monitor almost anything. Changing channels on a TV set via the controller accepting inputs from a remote control is a classic example. You can use the bus to also control volume, color hue and balance, contrast, and other video settings. You can turn LEDs off or on or feed an LCD display with alphanumeric. You can also read from and write to RAM, ROM, or Flash memory. You can use it to feed data to serial analog-to-digital converters (ADCs) and digital-to-analog converters (DACs). Some frequency synthesizers in cell phones and radios get their frequency settings via an I<sup>2</sup>C bus. With an embedded controller and I<sup>2</sup>C circuits, you can implement almost any special monitor or control function you want.

## I<sup>2</sup>C DERIVATIVES

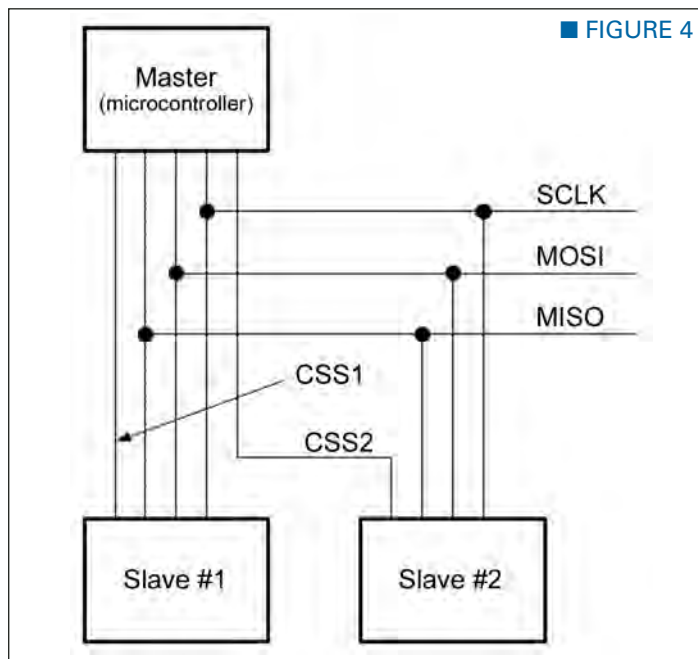
The I<sup>2</sup>C bus has proved to be so versatile and successful that it has spawned a number of offshoots and enhancements. The most notable are the ACCESS bus, SMBus, and PMBus. The ACCESS bus uses the I<sup>2</sup>C basic format and protocol, but goes further in adding a +5 volt line. This creates a four-wire bus where the +5 volt line can be used to power external devices such as displays, keyboards, and other peripherals.

The speed is set to 100 kbps and a maximum of 400 pF is designated for the bus capacitance. The ACCESS standard also specifies a type of cable up to 10 meters long





■ FIGURE 4



and appropriate connectors. The ACCESS bus also has some timing restrictions between transactions to permit multiple devices to arbitrate for the use of the bus.

The SMBus — also known as the System Management bus — was developed by Intel for use in controlling peripher-

al chips in Pentium-based PCs. It uses the basic I<sup>2</sup>C protocol, but may use some other supply voltage than +5 volts. It uses whatever the existing Vdd is in the system, like 3.3 volts. It also specifies a minimum 10 kbps clock that may also be as high as 100 kbps. The SMBus adds another bus line called ALERT. ALERT acts as an interrupt line from a slave back to the master. The SMBus also has a few timing restrictions, as well.

The PMBus stands for power management bus. With power management playing an ever more important role in implementing power supplies, there came a need for a bus to monitor and control power supplies. For example, the bus can turn DC-DC converters off or on, set their output voltage levels, set over voltage and over current levels, and monitor voltages to be sure they are what they should be. Temperature measurement is another common function. The PMBus is very similar to the SMBus and is gradually being incorporated into more power supply chips and modules.

## THE SERIAL PERIPHERAL INTERFACE

The serial peripheral interface (SPI) is similar to I<sup>2</sup>C in that it was created for inter-chip or on-board communications. It was created by Motorola (now Freescale Semiconductor) for use in exchanging data between multiple processors or other peripheral ICs like memories. It is typically incorporated into the processors as a common I/O interface.

Like I<sup>2</sup>C, it uses a master/slave architecture, but it has four lines and a ground, as shown in Figure 4. The lines are SCLK for synchronous clock, MOSI for master data out/slave input, MISO for master data input/slave output, and CSS for slave select. Some versions of the interface have multiple slave select lines (CSS1, CSS2, CSS3, etc.) to choose the target slave device.

Because of the two data lines (MOSI AND MISO), the SPI is full duplex meaning that masters and slaves can transmit and receive at the same time. The speed of the data transfers is also much faster than I<sup>2</sup>C or any of its derivatives. Most SPI can run at speeds up to about 20 Mbps. A typical rate is 4 Mbps. Data is transferred in multiple bytes.

SPI is often used only between two devices. It is hardwired so no addressing function is needed, saving lots of time. It is a good choice for transferring data between a regular microprocessor and a DSP chip or between a processor and a fast memory such as EEPROM. Other common uses are transferring data between processors and ADCs or DACs. Since multiple slave addressing is not usually available, it can be implemented in software, but the process is cumbersome and time consuming.

There are several other serial buses. Some examples are National Semiconductor's Microwire and Maxim/Dallas Semiconductor's one-wire bus. The CAN and LIN buses are also popular and are being increasingly used in cars and trucks. RS-232 is still widely used. The RS-422/3 and RS-485 buses are also common in industrial applications. USB and IEEE 1394 are fast serial buses. Really fast serial I/O such as Infiniband, RapidI/O, and Hypertransport, as well as Ethernet, use fiber optics — just that much more to talk about here in later issues. What is your choice? **NV**

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■ BY JON WILLIAMS

## PUTTING A WHOLE NEW SPIN ON EMBEDDED CONTROL

**WHEN I FIRST SAW THE ADS IN *NUTS & VOLTS* for the BASIC Stamp 1 (way back in 1993), I didn't believe it. I maintained an it's-just-too-good-to-be-true attitude, and actually put off buying my first BS1 for about six months. Well, for some, that's about to happen again. After a long, and sometimes arduous development cycle, Parallax has produced its first piece of custom silicon — the Propeller chip. No, it's not a microcontroller, it's a heck of a lot more — it's a multi-controller.**

**T**he clever guy who created the BASIC Stamp — Chip (yes, that really is his name) — has done it again. He's broken the perceived rules of what a small controller should be and how it should operate. He's long known what he wanted in terms of a small controller, and silicon manufacturing technology and his knowledge of microcontroller design have come to the point where he could make that dream come true. The great thing is that you and I benefit from having a cool new device that will enable us to make our [project] dreams come true and, in most cases, with just a bit of code and very simple hardware.

It all started back in 1998. Not satisfied with the state of microcontrollers, and frustrated with the effort required to manage complex tasks on a small micro, Chip set out to create his own. There were only a few rules: it had to be fast, it had to be relatively easy to program, and it had to be able to do multiple tasks without using interrupts — the bane of all but the heartiest of programmers.

That last rule is the kicker. How does one handle multiple tasks — even those with critical timing requirements — on a small processor that doesn't have interrupts, and do it

without making the programming chore a gigantic nightmare? Well, you do what we see happening more frequently in PCs these days — you use more than one processor.

First things first, and the first thing Chip had to do was develop the Propeller processor. After a lot of experimenting, Chip decided on a 32-bit engine. Mind you, this is not something you sit down and do with a handful of discrete components; creating a 32-bit processor from scratch requires special tools. Some of you may have noticed that a few years ago Parallax started offering development kits for high-end Altera FPGAs. Those actually started out as internal tools that Chip used to develop the processor core. The folks at Altera liked them, and they were working well for Parallax internal development, so it seemed like a good idea to make them available to the public.

The USB2SER adapter has similar origins. Another one of Chip's design rules is that the Propeller hardware be easy to program and not require expensive tools, hence the development of the USB2SER. It took about three years of very devoted work, but in the end the Propeller core emerged and Chip was able to test it full-speed

on an Altera FPGA.

Once that task was complete, the next step was to bring eight cores together to share a 32K RAM, a 32K ROM, cooperatively handle 32 I/O pins, and finally to transfer the design from the FPGA to custom silicon. Obviously, this was not a trivial task, but with Chip and his team, it finally came together. I can tell you that it was a very exciting day around Parallax when the first Propeller chips arrived and they came to life with one of the video demo programs that are used as a showcase of the Propeller's incredible capability.

### PROPELLER OVERVIEW

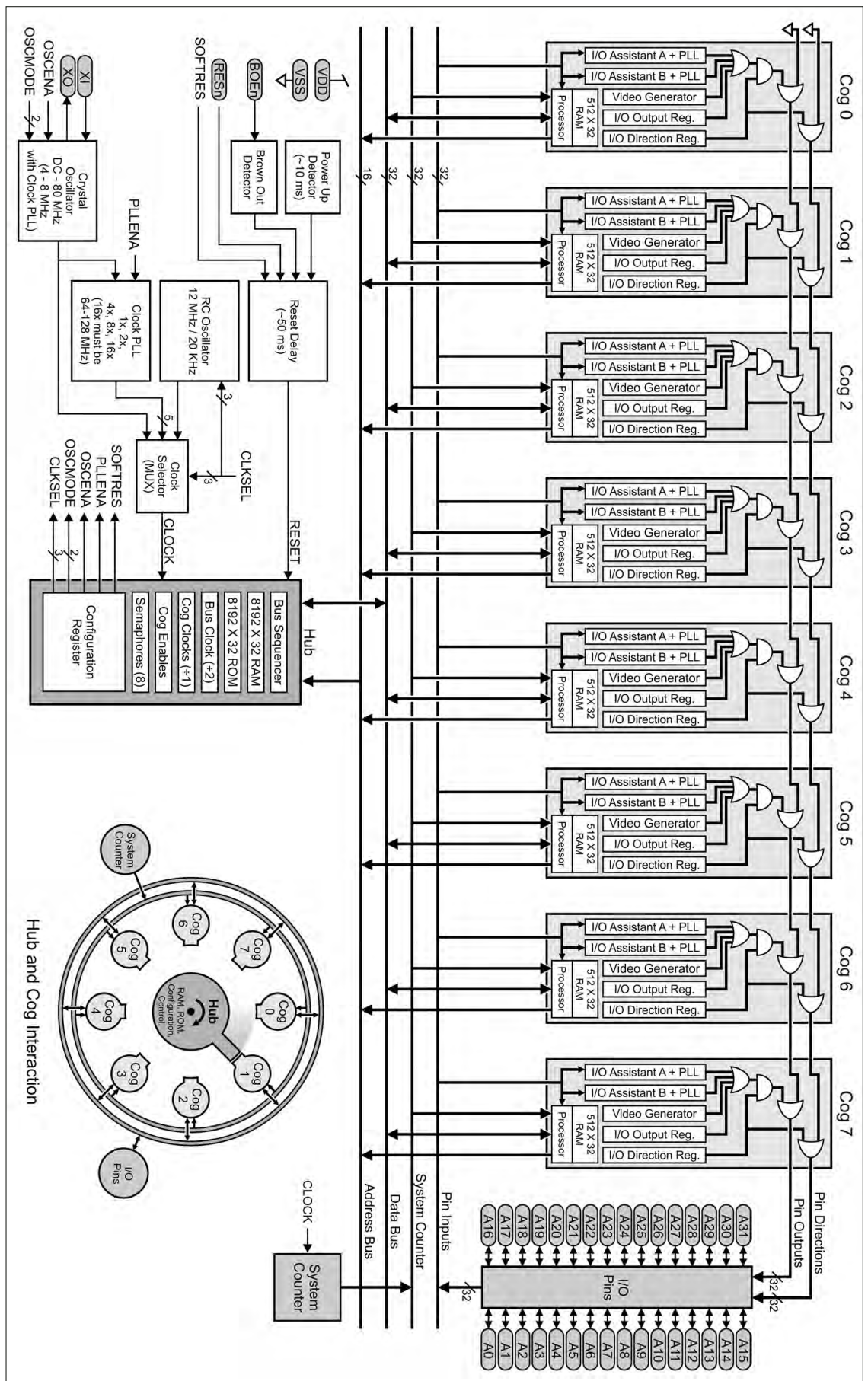
As I stated above, the Propeller chip consists of eight processor cores (called "cogs") that share access to a 32K ROM, a 32K RAM, 32 I/O pins, and other system resources. A system manager called the "hub" takes care of keeping the cogs coordinated. Figure 1 shows a graphic depiction of the Propeller architecture.

Shared resources come in two types: common and mutually-exclusive. The I/O pins, for example, are common in that any cog can access any pin at any time. This is

possible because the direction registers for each cog are OR'd together before the final I/O stage. If any cog makes a pin an output, it will be an output. The same is true for the output state — if any cog that defines a pin as an output makes the pin high, that pin will go high. Note that inactive cogs or cogs that define a pin as an input have no effect on the output state of any pin.

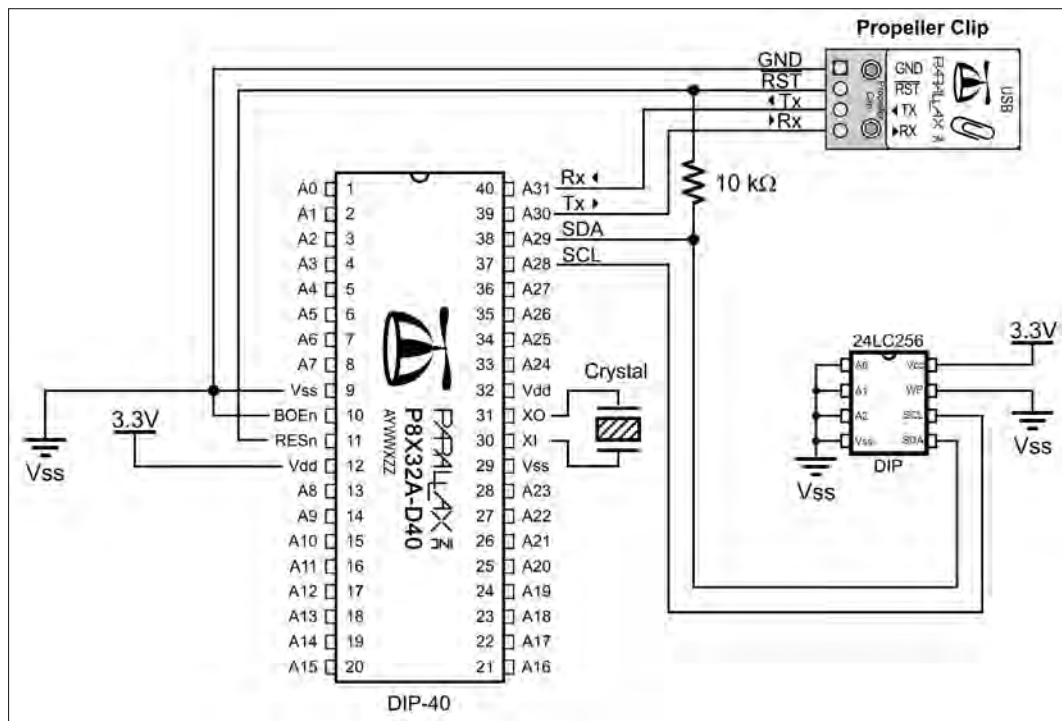
Another common resource is the system clock. This actually drives all cogs and allows them to be synchronized, even though they run independently of each other. The system clock also drives a global register called the System Counter. This 32-bit, read-only counter increments every clock cycle and can be read by any cog via the CNT register. A command called WAITCNT can be used by a cog to wait for a specific value in the CNT register — this is handy for creating custom delays.

The system RAM is a mutually-exclusive resource, which means that the hub manages access to it, allowing any cog access, but only one at a time. This prevents one cog from clobbering a value being written



■ FIGURE 1. Propeller Block Diagram.





■ **FIGURE 2. Propeller System.**

24LC256 EEPROM (at address %000) connected to pins A28 (SCL) and A29 (SDA). If the EEPROM is detected, the contents are transferred to the Propeller RAM and the program for cog #1 is started. Note that you can, in fact, do development work on a Propeller Chip without an EEPROM, as the Propeller Tool allows you to download and run a program right from RAM. This is very convenient for testing new code without overwriting what already exists in the system EEPROM. Just remember that a Propeller system without an EEPROM that is not

by another. The neat thing about using a shared RAM is that it's an easy way for cogs running different processes to share information. One might write an application where a cog is devoted to monitoring a serial stream and parsing data from it, placing that data in a shared RAM location. Processes running on other cogs can read the shared RAM as required to use that data.

## GETTING CONNECTED

The simplest, practical Propeller system consists of a Propeller chip, a 24LC256 EEPROM, a 3.3 volt power

supply, and a programming connection. If you build your own system, you either use the USB2SER connector or a derivative of it called the Propeller Clip. Both devices carry the same signals, although they have different layout and connection schemes, so be mindful of that in your designs. The Propeller Clip is designed to clip right to the edge of a PCB, requiring nothing more than a set of pads.

If you look at the simple system schematic in Figure 2, you'll see that four of the Propeller's 32 I/O pins serve a special purpose at boot-up. Pins A30 and A31 provide the serial connection to the programming environment (called the Propeller Tool). If a programming host is detected, the Propeller will converse with it to identify itself and possibly download a new program into the global RAM, and if commanded to do so, will also transfer that program into the EEPROM.

If no host is detected, the Propeller looks for the

connected to the programming tool will do nothing but put itself to sleep.

And for those of you wondering if you can hang other I<sup>2</sup>C devices from pins A28 and A29 ... of course you can. Just be sure you don't write anything to the Propeller's EEPROM or else you could corrupt it and prevent the Propeller from running properly after the next reset.

Let's stick with the idea of a typical system as on the Propeller Demo Board shown in Figure 3. When the system starts, the user programs will be transferred from EEPROM to the Propeller RAM and the program for cog #1 is started. The Propeller can be programmed in two languages: Spin — its high-level language — and Propeller assembly. That said, even a pure assembly program gets started with a tiny bit of Spin code to make sure that things take off properly.

## OBJECTS IN THE MACHINE

Spin is an object-based language which provides structure and code reusability. This is good for us mere mortals, as advanced programmers (like Chip) can write cool modules like the video driver and floating point



■ **FIGURE 3. Propeller Video Demo.**



library, and all we have to do is include them into our programs! How great is that?

As stated earlier, Propeller objects can be programmed with Spin and, optionally, Propeller Assembly code. Regardless of the programming mix, objects are stored as .spin files, and each .spin file is a discrete object. Like other object-oriented languages, one object can include and, indeed, be built from other objects. When one object is created using others, it becomes known as the “top” object.

When a program is written, it can be compiled and downloaded directly to RAM for testing or, optionally, it can be downloaded to RAM and then transferred to the Propeller EEPROM. Remember that this last step is required for stand-alone operation. The last program loaded into the Propeller EEPROM will be loaded and run after the next reset if no programming connection is present.

You might wonder what happens if the same object is used more than once in a Propeller project. Not to worry — the compiler optimizes the code space removing any redundant code with its object distiller engine. Once the code is downloaded and run, the Propeller will load the Spin interpreter from its internal ROM to any cog that needs it (i.e., that is running Spin code). Not all cogs will require the interpreter. You can, for example, have one cog load an assembly program into another cog and start it. This is useful when you absolutely need the most performance out of a cog (the video module is an example where this is done). In a situation where one cog is used to launch an assembly program into another, the “launcher” cog is freed-up as soon as the other program is started.

Okay, we have to learn to walk before we can run (especially on eight legs!), so let's do the ubiquitous “Hello, World!” LED blinker program that we always start with when we get something new. Here's the complete listing:

```
CON
  _clkmode = xtall + pll16x
  _xinfreq = 5_000_000

  Led = 16

VAR
  long delayTime

PUB BlinkLED

  dira[Led] := 1

  repeat
    outa[Led] := !outa[Led]
    delayTime := cnt + 8_000_000
    waitcnt(delayTime)
```

The truth is, we could have made this simpler, but this demo lets us show off some neat hardware features of the Propeller and gives you an idea of how the code is structured. You'll notice right away that things are organized into blocks; in this program, there is a CON (constants) block, a VAR (variables) block, and a PUB (public) block. There are other block types, including OBJ (object), PRI (private), and DAT (data) blocks. One of the [many] nice

features of the Propeller Tool is that each block gets its own color-coded background. And, in those cases where you have two consecutive blocks of the same type, there are light and dark versions of each background color.

In the CON block, we start by setting the system clock mode (to external crystal) and enable the PLL (phase locked loop) to multiply the clock frequency by eight. This is done by setting switches in the hub where the system clock is controlled. That's right — the Propeller PLL multiplies the external clock by 16x and provides us taps at 1x, 2x, 4x, 8x, and 16x. So, what we've done is taken our external 5 MHz crystal and wound it up to 80 MHz! Note that 80 MHz is the maximum internal speed, so don't get the idea that you can drop a 20 MHz crystal onto the Propeller and wind it up to 320 MHz — this is not going to work. Remember that 16x is the maximum. If we wanted to back the internal clock down to 20 MHz, all we have to do is change the PLL tap to **pll4x**.

The final step in the constants definition block is to set a pin to use for the LED. In this case, we're selecting A16 (which has an LED right on the Propeller Demo Board).

For this simple program, we're going to use just one variable, and we'll make it the native Long (32 bit) type, as this is the same size as the system counter that we're about to make use of. The Propeller can also use Word (16 bit) and Byte (8 bit) variables. Just be aware that the 32-bit processor handles 32-bit variables most efficiently.

The working part of the program is contained in the PUB section. Public blocks can be “seen” by other objects in a multi-object project — private blocks cannot. We will always have at least one public block in an object. The first step in our blinker program, then, is to make the LED control pin an output. This line:

```
dira[Led] := 1
```

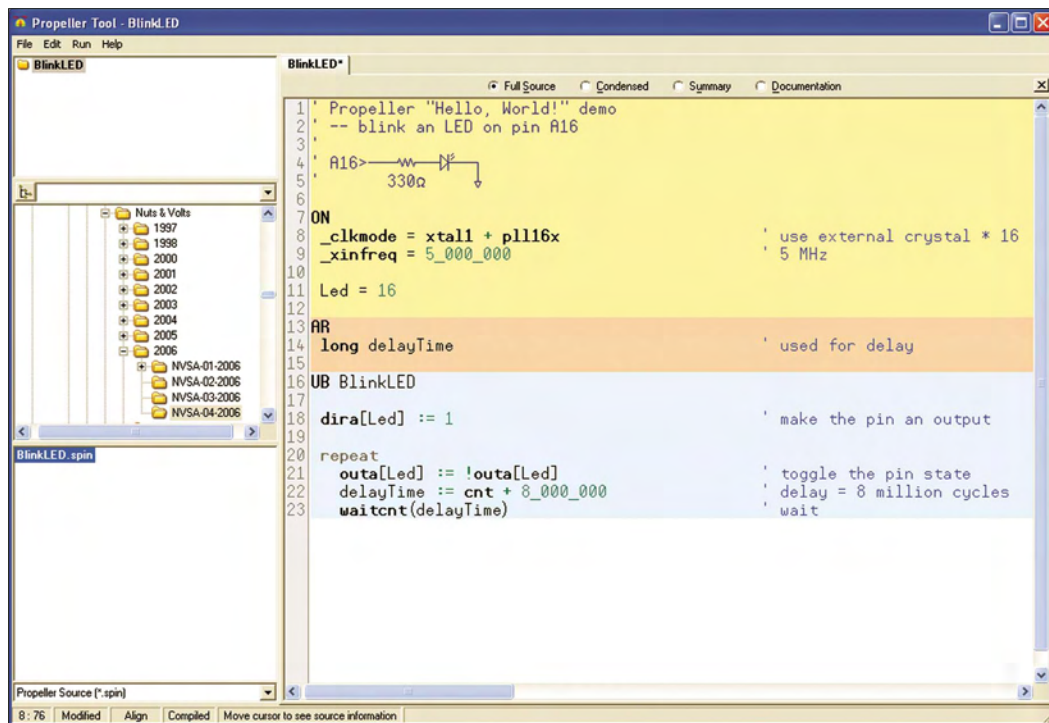
... is equivalent to the PBASIC line:

```
DIRS.LOWBIT(Led) = 1
```

Some of you will recognize the assignment operator that is borrowed from Pascal. Spin is a really cool language, taking advantage of features found in other popular programming languages. Block definition by indenting — something found in Python — is one of those features.

The rest of the program forms an infinite loop using just the **repeat** keyword. Note that the three lines that follow **repeat** are indented to the same level — this identifies them as a code block. I know that a lot of you think I'm wacky for my “neatness counts” campaign when it comes to code formatting. Well, here's why. If we don't indent properly, then the program won't run properly. The great thing is that by using indenting instead of block terminators we don't have to type as much. Chip loves efficiency and this is one of the many areas related to the Propeller where it shows up.

Okay, let's see how the program works. The first line in the indented block inverts the state of the output pin to toggle the LED. The second line reads the current value of



■ FIGURE 4. PropellerTool.

the system counter (in a global register called **cnt**) and adds eight million (zoiks, that's a big number!) to it,

saving the new value in the variable *delayTime*. The heart of the loop is with the **waitcnt** instruction that will

hold this cog's program until the value of the system counter matches the value passed to it. So, with a system clock of 80 MHz, waiting eight million cycles causes a 100 millisecond delay (8 divided by 80 is 0.1).

Yes, I know it seems a little silly to blink an LED with a multi-controller that can run at up to 80 MHz, but we have to start somewhere. Please believe me when I say that we haven't even begun to scratch the surface of the Propeller, or even the Propeller Tool. One thing that I will point out is that the Parallax True Type® font includes schematic symbols — yes,

we can even draw simple diagrams right in our listings! If you look carefully, you can see the LED schematic in the listing shown in Figure 4.

And for those of you worrying about the BASIC Stamp or SX micro-controller going away — the answer is, “No, of course not.” Both are doing well, and now they have a big brother. Parallax recognizes that customers come in all shapes, sizes, and desires for what they want in a product, and the Propeller simply expands the line for those that are looking for a little (okay, a lot) more horsepower for their projects.

If your head isn't spinning (sorry, couldn't help myself) by now, then you're made of tougher stuff than me! Next month, we'll take it to the next step by using some of the pre-written objects provided by Parallax and create one of our own. It may take us a while to master the Propeller, but I can promise you that we will have a lot of fun along the way.

Until then — Happy Spinning! **NV**

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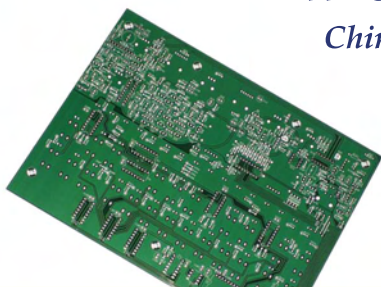
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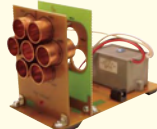


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### Multiple message storage!

The Bullshooter-II provides up to 8 minutes of digital voice storage that can be broken down into 8 separate stored messages! Great for announcements, etc. Built-in mic plus external input. Runs on 12VDC or our AC125 PS.

BS2C Bullshooter-II Kit \$69.95

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### Now YOU can be the cop!

Our famous Speedy radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. 1/8th mile range is typical. You supply two coffee cans! Runs on 12VDC or our AC125 power supply.

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### Find that transmitter quick!

Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.

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### Read the number dialed!

The Tone Grabber captures dialed phone numbers, repeater codes, control codes, or anything that uses touch-tone signaling. Flash micro stores 640 digits! Phone line and audio inputs. Runs on 12VDC or our AC125 PS.

TG2C Tone Grabber Kit \$69.95

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Super Hi-Q ferrite rod antenna with Faraday shield eliminates noise from power lines, dimmers, static and more! Great results from 500kHz to 15MHz. Super for AM broadcast band! Includes power supply.

SM100 Sig Magnet Kit \$89.95

# Mini-Kits... The Building Blocks!

## Tickle-Stick



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light! Great fun for your desk. "Hey, I told you not to touch!" Runs on 3-6 VDC

TS4 Tickle Stick Kit \$12.95

## Super Snoo Amplifier



Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watts output. Makes a great "big ear" microphone. Runs on 6-15 VDC

BN9 Super Snoo Amp Kit \$9.95

## Dripping Faucet



Produces a very pleasant, but obnoxious, repetitive "plink, plink" sound! Learn how a simple transistor oscillator and a 555 timer can make such a sound! Runs on 4-9 VDC.

EDF1 Dripping Faucet Kit \$9.95

## LED Blinky



Our #1 Mini-Kit for 31 years! Alternately flashes two jumbo red LED's. Great for signs, name badges, model railroading, and more. Runs on 3-15 VDC.

BL1 LED Blinky Kit \$7.95

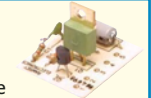
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Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch, or to turn on a recorder or light! Runs on 6-12 VDC and drives a 100 mA load.

VS1 Voice Switch Kit \$9.95

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Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Runs on 5-12 VDC and will drive any load up to 100 mA.

TD1 Encoder/Decoder Kit \$9.95

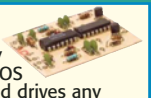
## RF Preamplifier



Super broadband preamp from 100 KHz to 1000 MHz! Gain is greater than 20dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7 RF Preamp Kit \$19.95

## Touch Switch



Touch on, touch off, or momentary touch hold, your choice! Uses CMOS technology. Runs on 6-12 VDC and drives any load up to 100 mA.

TS1 Touch Switch Kit \$9.95

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- ✓ It's impossible to give you full specs on these products in a 1" space!
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# What's New For 2006!

## The Newest And Neatest Goodies

### Digital FM Stereo Transmitters

- ✓ Monitors the entire aircraft band without tuning!
- ✓ Passive design, can be used on aircraft, no local oscillator, generates and creates no interference!
- ✓ Great for air shows
- ✓ Patented circuit and design!

For decades we have been known for our novel and creative product designs. Well, check this one out! An aircraft receiver that receives all nearby traffic without any tuning. It gets better... there is no local oscillator so it doesn't produce, and can't produce, any interference associated with all other receivers with an LO. That means you can use it onboard aircraft as a passive device! And what will you hear? The closest and strongest traffic, mainly, the one you're sitting in! How unique is this? We have a patent on it, and that says it all!

This broadband radio monitors transmissions over the entire aircraft band of 118-136 MHz. The way it works is simple. Strongest man wins! The strongest signal within the pass band of the radio will be heard. And unlike the FM capture effect, multiple aircraft signals will be heard simultaneously with the strongest one the loudest! And that means the aircraft closest to you, and the towers closest to you! All without any tuning or looking up frequencies! So, where would this come in handy?

1. At an air show! Just imagine listening to all the traffic as it happens
2. Onboard aircraft to listen to that aircraft and associated control towers
3. Private pilots to monitor ATIS and other field traffic during preflight activities (saves Hobbs time!)
4. Commercial pilots to monitor ATIS and other field traffic as needed at their convenience
5. General aircraft monitoring enthusiasts

Wait, you can't use a radio receiver onboard aircraft because they contain a local oscillator that could generate interfering signals.

We have you covered on that one. The ABM1 has no local oscillator, it doesn't, can't, and won't generate any RF whatsoever! That's why our patent abstract is titled "Aircraft band radio receiver which does not radiate interfering signals". It doesn't get any plainer than that! Available as a through-hole hobby kit or a factory assembled & tested SMT version.

ABM1	Passive Air Band Monitor Kit	\$89.95
ABM1WT	Passive Air Band Monitor, Factory Assembled & Tested	\$159.95

#### SPECIFICATIONS

Frequency Range:	118 MHz to 136 MHz
Receiver Type:	Patented Passive Detector
IF Frequencies:	None!
Receiver Sensitivity:	Less than 2 uV for detectable audio
Audio Output:	700mW, 8-24 ohms
Headphone Jack:	3.5mm stereo phone
External Antenna:	Headphone cord coupled
Power Requirement:	9VDC battery
Dimensions:	2.25" x 2.8" PC Board 2.5" x 4.6" x .9" Case
Weight:	4 oz. with battery

### Hand Held Wind Speed Anemometer

- ✓ Displays instantaneous wind speed!
- ✓ Stores & records maximum gusts and averages!
- ✓ Displays temperature and wind chill in °F or °C!
- ✓ Beaufort wind scale bargraph!

We have all seen them on TV... the professional weather talent (now known as meteorologists!) standing in the middle of the hurricane report holding up their wind meter clocking the fastest wind gusts. Usually that's just before they get blown to the ground along with their producer and camera crew! Well now you can have the same professional wind speed meter on a hobbyist budget! Besides displaying the realtime instantaneous wind speed in your choice of MPH, KM/H, M/S, or Knots, it also stores and records the maximum gust AND average since it was powered up! In addition, realtime wind speed is also displayed on a Beaufort wind scale ranging between 0 and 12. Housed in a rugged, weather resistant case and includes a neck strap for easy carrying. Runs on a single lithium button cell that is included. Factory assembled, tested, and ready to go!

EA3010	Handheld Wind Speed Anemometer	\$49.95
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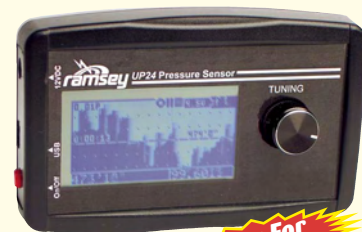


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- ✓ Shows realtime elevation & pressure changes!
- ✓ USB computer interface for easy data transfer!
- ✓ 13,824 samples of FLASH storage available!
- ✓ Special pilots menu
- ✓ Multiple built-in alarms



New For 2006

## "The Most Advanced And Accurate Ramsey Kit To Date!"

We really did it this time! The UP24 is one of our most advanced kits to date, and an absolute MUST for anyone serious about the environment around us! But the applications only begin there.

The unique design allows unprecedented super high resolution measurements and display of absolute atmospheric air pressure. The UP24 senses ambient air pressure and critically calculates elevation with unheard of precision! Using a highly sensitive sensor and 24-bit A/D converter in a special noise-immune design, less than 1/3" of an inch of elevation resolution is achieved! YES, we said 1/3 of an inch! This high accuracy and resolution opens the door to a host of sophisticated environmental air pressure monitoring applications.

Unlike your normal run-of-the-mill barometer, air pressure is sensed in Pa's or kPa's. What are those you may ask? Pascals or KiloPascals. However, don't be afraid, for your convenience, and to fit any application you may have, it is also displayed in millibars, bars, PSI, atmospheres, millimeters of mercury, inches of mercury, and feet of water! Take your pick! The range of the UP24 is 15kPa to 155kPa.

We've talked about air pressure, now let's talk about elevation! The incredibly precise 24 bit A/D converter in the UP24 looks at the air pressure and converts it to elevation above sea level. In both graph and text, the elevation is displayed to a resolution of 1/3"! Yes, I said 1/3 of an inch! The applications for the super accurate elevation meter are endless. From watching and recording elevations during hiking trips to measuring and recording the wave heights on boats! Let your imagination take over from there!

What if you're in the field and you want to save data captured in your UP24? The built-in FLASH storage provides 13,824 samples of storage. Then you can transfer your data to your PC with a standard USB interface.

While the UP24 is small enough to be kept in your coat pocket it boasts a large 2.78" x 1.53" 128x64 pixel LCD display screen making viewing easy. Display modes include both realtime pressure and elevation graphs as well as pressure and elevation statistics. There are 12 user selectable sample rates from 1/10th of a second all the way up to every 15 minutes.

Needless to say, you cannot put all the specs and screen shots in the limited space of this ad! Visit our website at [www.ramseykits.com](http://www.ramseykits.com) for full specs and information.

If you're looking for the finest air pressure and elevation sensor, check out the UP24, truly a marvel in the industry! Available in a ready-to-build kit or a factory assembled and tested version. Check our website at [www.ramseykits.com](http://www.ramseykits.com) for more information!

UP24	High Resolution Air Pressure/Elevation Sensor Kit	\$239.95
UP24WT	Factory Assembled and Tested UP24	\$299.95
AC125	110VAC Power Adapter/Charger	\$9.95

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## WHAT'S UP:

January's power transformer advice was a hit, so here's the sequel — plus the usual scattering of circuits.



Digital wind vane.



High-power T-Bird lights.



USB power booster.



Vacuum tube power amps.

## WITH TJ BYERS

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, comments, or suggestions.

You can reach me at: [TJBYERS@aol.com](mailto:TJBYERS@aol.com)

## TRANSFORMER RATINGS, AGAIN

**Q** I have the same 24VCT transformer that you talked about in the January '06 issue. I am using the transformer for my three stepping motors (2A/stepper) and would like to eventually add a fourth stepper. Using your data, that means the transformer won't be able to supply the extra current — unless I use an inductor. What value of inductor would you use?

— Michael Elledge  
Christmas, FL

**A** The drawing in Figure 1 shows the voltage and current values to expect from a full-wave rectifier with a

choke input. Notice that the output current of both configurations has increased by 33% — and, in the case of the center-tapped rectifier, it even exceeds the transformer's AC current rating. The choke input can do this because energy is stored in the magnetic field which wants to keep current flowing at a constant rate, and will take energy from its own magnetic field if needed to maintain that current flow.

The value of the inductor depends on many factors. First, there must be sufficient inductance to ensure continuous operation of the rectifiers and provide good regulation. The absolute minimum inductance is given by the equation,  $L_{min} = (K / f) * R_L$ , where L is expressed in Henries. For 60-Hz line operation, the formula becomes  $L_{min} = R_L / 1000$ .

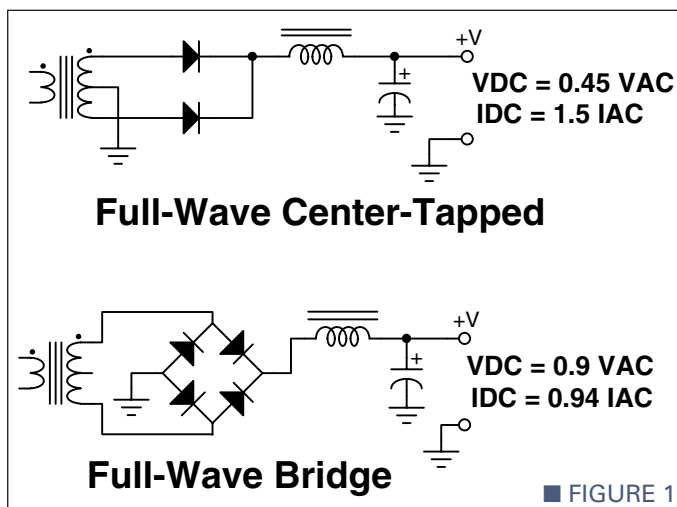
You may see this formula reduced to  $L_{min} = V_{out} / I_{out}$ . Let's say that your power supply is 12 volts at two amps. Plugging these values into the equation, we get 6 mH ( $L = 12V / 2A$ ). Remember though, this is the absolute minimum inductance needed to sustain filtering — and not a practical

value. A rule of thumb is to multiply  $L_{min}$  by at least 10. For our example — Figure 2 — that value is 60 mH.

Next, we have to calculate for the value of the capacitor. The LC product must exceed a certain minimum to ensure a desired ripple factor. For this, you need to solve the equations for a first-order low-pass filter. This is more math than I care to do on a daily basis, so I use software simulation instead. Any decent schematic capture/simulator package will work. If you don't have a simulator, I recommend eSketch from Schematica ([www.schematica.com](http://www.schematica.com)), which sells for \$69. Using the values shown, the ripple is a low 44 mV.

For an eight-amp output, you need to do the math all over again, starting with the inductor. If you do, calculate for the lowest anticipated current. That is, if you don't run all four steppers all the time, go with the lowest total current because it's the most critical inductor factor.

In actuality, the output voltage will be 10.8 volts, and that assumes perfect devices. You need to take into account resistance loss in the inductor and other wiring, which lowers the voltage even more. Inductors like this are hard to come by — and expensive when you can find them. The alternative would be to wind your own. On the upside, it does reduce the size of the filter cap considerably. Me? I'd spend my money on a bigger power





transformer, then isolate the outputs for each stepper (using a diode) and filter each using a hefty capacitor ( $C = I_{out} / 120 * V_{RIPPLE}$ ).

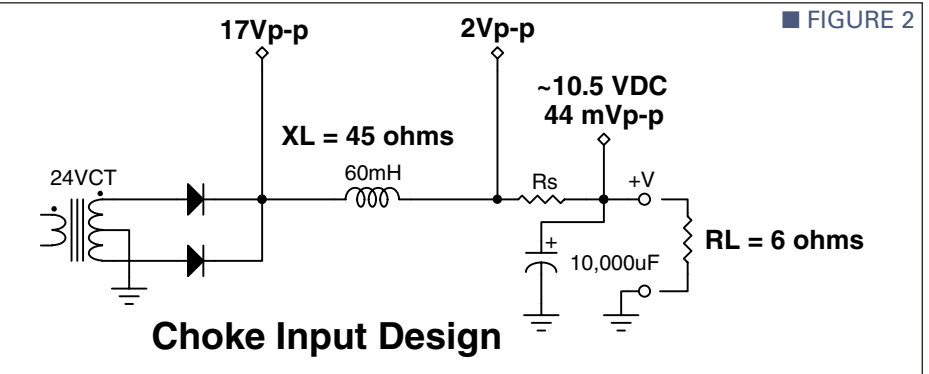
## DOOR OPEN BUZZER

**Q** I have a Chamberlain garage door monitor that notifies me when the garage door is open or closed. When the door is closed, a coded radio signal is sent to a receiver, which displays a green LED. When the door is open, a red LED flashes once every second for as long as the door remains open. The system works great, but I would like to add a buzzer in addition to the flashing red light when the door opens. However, I don't want the buzzer on all the time when I'm working in the garage with the door open. I want the buzzer to just initially sound for the door opening and then stop. I was thinking of using the "Adjustable Buzzer" circuit in the December '05 column, but I'm not sure how to adapt it for my purposes. Do you have a good solution?

— Christopher Rust  
Maple Grove, MN

**A** It's fortunate that you have a steady green LED in addition to the blinking red LED, because it's nearly impossible to trigger a timer from a pulsing source. I suggest you take the trigger signal from the green LED when it extinguishes — the opposite of the "Adjustable Buzzer" design. Instead of a 555 timer, I chose to go with a NOR gate monostable timer (Figure 3). When the green LED goes dark, the 4N25 optoisolator turns off and applies a high to the 4001 NOR gate. This starts the timer and turns on the buzzer. The time is determined by  $t = 1.1RC$  — about five seconds for the values shown.

Want the buzzer to beep in step with the blinking red LED? Use the optional beeper circuit under the buzzer diagram. When the red LED is lit, Q1 turns on and sounds the buzzer. Closing



the garage door illuminates the green LED and effectively disables the timer — until the next open-door incident.

## WHICH WAY THE WIND BLOWS

**Q** I would like to build a weather vane to show the direction of the wind on a display inside my shop. Ideally, it would have LEDs to indicate at least eight wind headings. Instead of a mechanical contact at the vane, is there a simple circuit to indicate the position

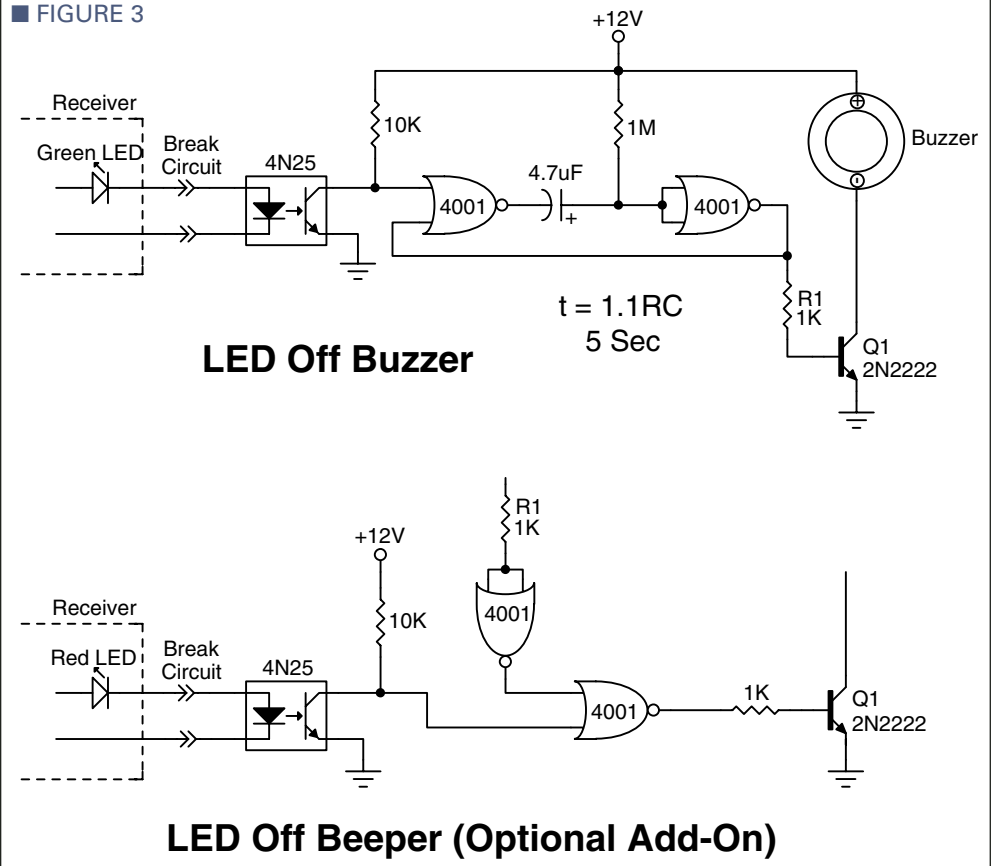
of the vane? Perhaps a series of Hall-effect components have to be used? I'm not sure if I understand the Hall-effect components correctly, but I'm open to anything and willing to try (read: limited electronic, self-taught, hobby education).

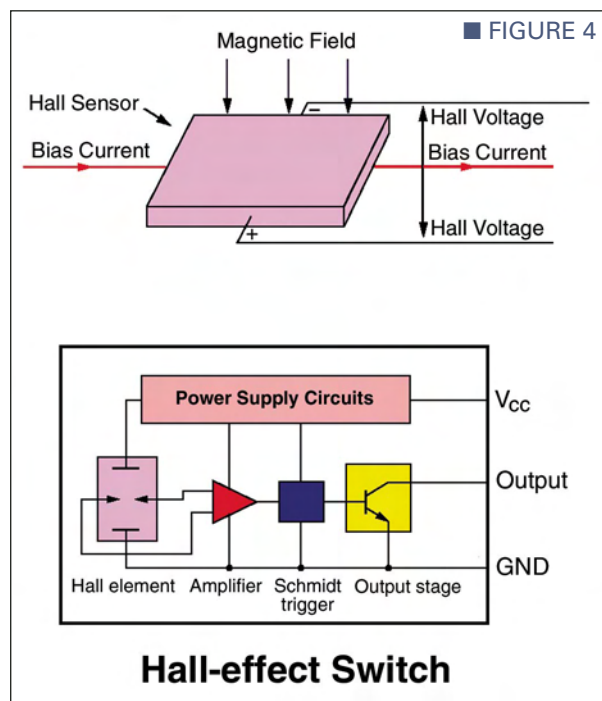
— Larry

**A** Welcome to the world of self-taught hobby electronics. The road is bumpy, but filled with lots of serendipity detours that lead to exciting discoveries. Let's start with the Hall-effect.

In operation, a constant bias

■ FIGURE 3



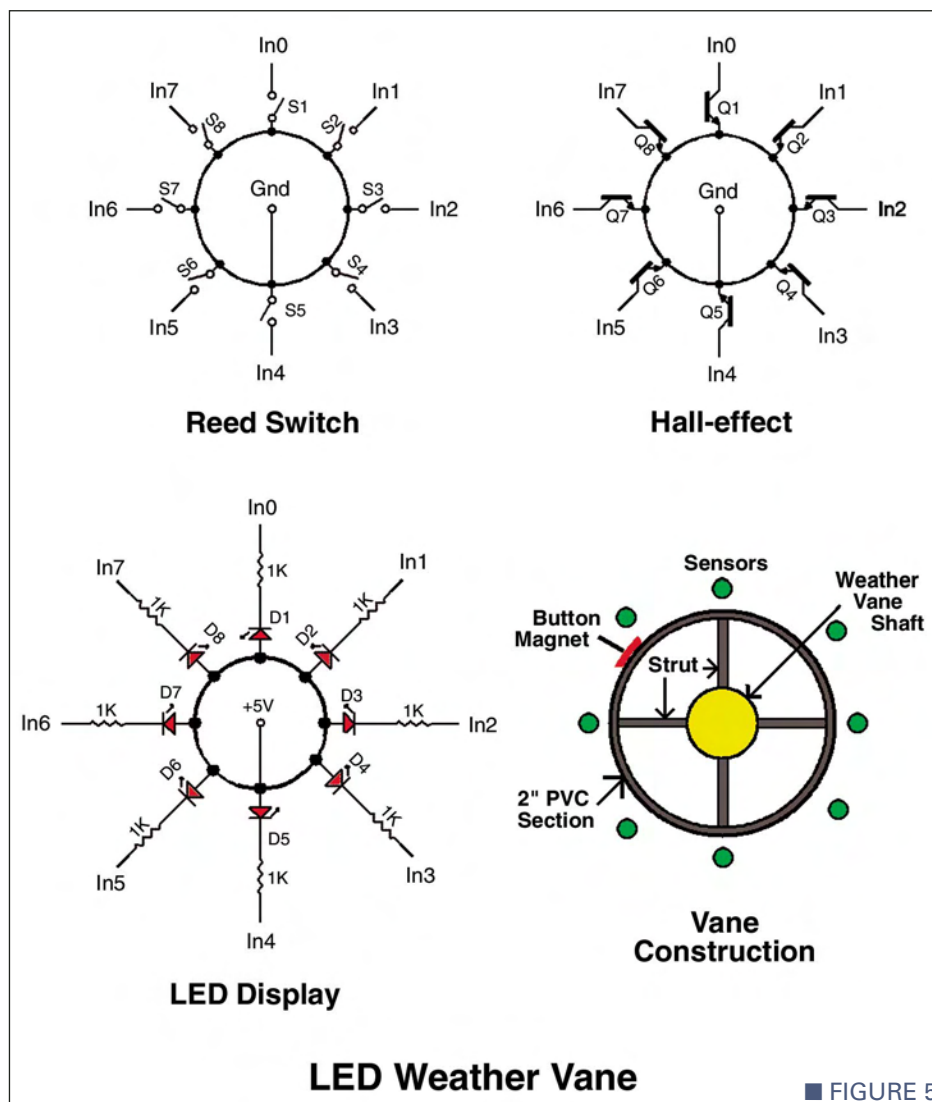


current is passed through the Hall sensor. In this mode, the current (flow of electrons) is evenly distributed across the chip. With an equal number of electrons at the chip edges, no voltage exists at the output. When the Hall sensor is placed in a magnetic field, the electron flow is forced to one side of the chip causing an imbalance in the electron concentration at the edges (Figure 4). This creates a voltage output that is detected and amplified to switch on an output transistor.

On to the weather vane circuit — eight Hall

sensors are placed around the vane shaft in positions of north, north-east, east, south-east, etc. A magnet is cemented to a PVC ring attached to the vane's shaft. When the magnet comes in proximity to the Hall sensor, the transistor turns on and lights a corresponding LED on the circular display (Figure 5). The 1K resistor determines the brightness of the LED and the lower the resistance, the brighter the LED. Can't find a suitable Hall-effect sensor (the Panasonic DN6849 from Digi-Key looks like a good bet)? You can substitute a reed switch in its place, as shown in the schematic to the top left. (See how serendipity works in hobby electronics? If you don't have one part, lots of times another will work.)

The weather vane sender can be connected to the LED display via a CAT 3 or CAT 5 communications cable. However, this can get expensive on long runs. A solution is to encode the eight inputs into BCD code and send it over the twisted pairs of cheap telephone wire (Figure 6), then decode it back to the original eight outputs. I hope you have learned something and had fun doing it at the same time. Have fun with your weather station!



## SILICON CONTROLLED SWITCH

**Q** Could you please explain the theory of operation of the new SCRs with turn-off gate and small current applications?

— B. John

**A** What you are describing is a Silicon Controlled Switch (SCS) — sometimes called a tetrode thyristor. Like a Silicon Controlled Rectifier (SCR), the SCS is a four-layer device that goes into the avalanche mode when a positive voltage is placed on the cathode gate — and will continue to conduct even after the gate voltage is removed. The current flow is stopped by interrupting the current, a situation called natural commutation. The SCS, on the other



hand, has an additional gate connected to the anode side of the device. When a negative voltage is applied to the anode gate (or the anode is shorted to the cathode), it can turn off the SCS through forced commutation. A typical SCS circuit is shown in Figure 7.

The four-layer SCS structure is equivalent to an NPN and a PNP

transistor configured in a forced feedback situation. When the ON push-button is pressed, voltage is applied between the cathode gate and the cathode, forward-biasing the lower transistor and turning it on. This, in turn, causes current to flow through the upper transistor's base junction via R2 and turn it on. The SCS is now locked on, causing the motor to start and run — even after the ON switch is opened.

Pressing the OFF push-button shorts the anode terminal to the cathode. This causes the upper transistor to lose its emitter current and break the current flow to the base of the lower transistor. The SCS now loses its lock on the anode/cathode current flow and turns off the motor. The SCS will remain in the off condition until the ON button is again pressed.

SCS devices are not as widely used as once seemed possible. Their low use is likely due to the peak current that

could be reliably turned off by the anode gate. Consequently, they are hard to find and often expensive. However, I was able to locate a small cache of the 3N86 at a reasonable price from Wholesale Electronics ([www.weisd.com/store2/JS3N86.html](http://www.weisd.com/store2/JS3N86.html)). It's rated 65 volts at 200 mA, which will limit your experiments and applications.

## HIGH-POWER T-BIRD FLASHER

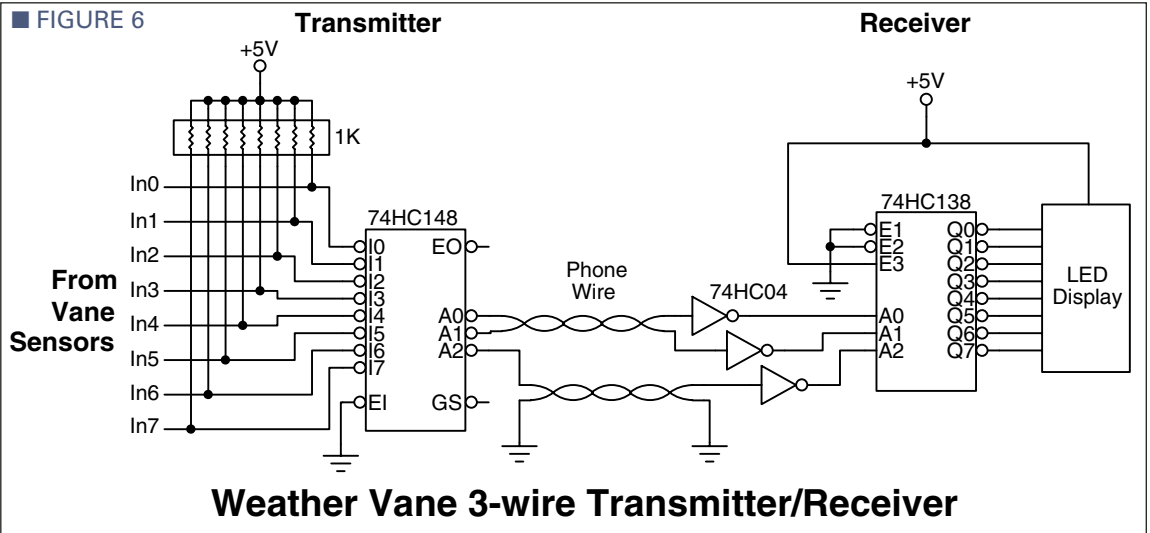
**Q** I am looking for a schematic for sequential lighting of tail lights in my '70 Mustang. Ford made these for their Cougar models. I would also like to control the speed of the sequence. Could I use some small relays to

accomplish this? I have #1157 bulbs.

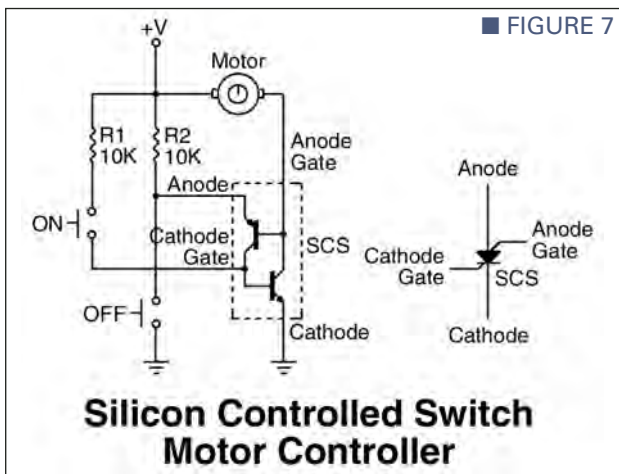
— Jim Wiggins

**A** I published a circuit that does exactly this in the March '06 issue, but it can only light an LED — not your eight-watt bulb. So, I went back to the drawing board and came up with the circuit in Figure 8. This design uses sensitive gate SCRs — like the Teccor TCR22-3 (available from Digi-Key; 800-344-4539; [www.digikey.com](http://www.digikey.com)) — to light your existing bulbs. SCRs are tricky, in that once they are turned on, they remain on. Just what you want from the staircase pulses of the 4017 decade counter. But once all the lights are lit, they have to be turned off to start the

■ FIGURE 6

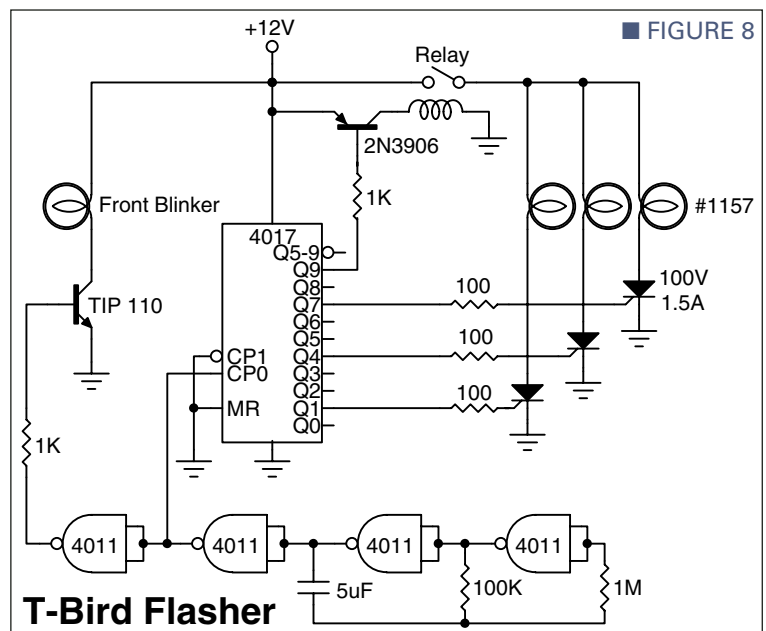


Weather Vane 3-wire Transmitter/Receiver



■ FIGURE 7

Silicon Controlled Switch Motor Controller

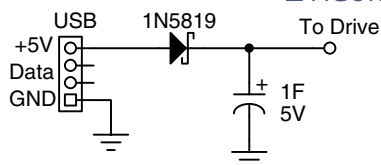


■ FIGURE 8

T-Bird Flasher



■ FIGURE 9



## USB Power Boost

ripple effect over again. Well, the only way to turn off an SCR is to cut the power, which is what the relay does. The Q9 output of the 4017 is normally low, which engages the relay via the 2N3906 transistor. When Q9 goes high, the relay opens and turns off the SCRs.

The 4017 is clocked with a pair of NAND gates — in an astable configuration — that turns on the lamps a half second apart. To adjust the speed of the timing sequence, replace the 100K resistor with a 250K pot. Since I had an unused gate, I used it to drive a TIP110 Darlington transistor that flashes the front turn light. It's optional and not critical to the circuit. That's it. As simple as the original Ford version, but without the cams.

## USB POWER BOOST

**Q** I have several 2.5" hard drive enclosures that claim to be USB powered. But, as you know, some machines just

don't have sufficient current capabilities on their USB ports to power these devices. What I have discovered is that once the drive is up to speed, there is usually sufficient current to keep it running. I would like to build an in-line power supply using AAA or AA batteries to provide the boost necessary to get the drive spinning. The power supply should be invisible to the host PC, while simultaneously being paralleled with the USB power, with maybe a (automatic) switch to remove the "power box" from the picture after the drive has spun up. Can you help?

— David Draper  
Bakersfield, CA

**A** You have need for concern. Although the USB port is rated for five volts at 500 mA, many notebook USB ports can only deliver 100 mA. While a battery boost would help, I suggest using a supercap instead. Because the supercap has a lower internal resistance than an AA cell does, it can provide a bigger jolt of current.

In fact, the motor and capacitor curves match up perfectly. The motor demands a larger amount of current to start from a stall than it takes to operate at full speed, whereas the capacitor has the most current to give at the beginning of its discharge curve and loses energy as the cap discharges. By balancing the

charge in the capacitor with the needs of the motor, the voltage will remain high enough for long enough for the motor to wind up and let the USB port take over.

A one Farad supercap can store enough energy to power most disk drives for three seconds with little sag in the voltage (less than a volt) as the cap discharges — plenty of time for most drives to be in high gear — at which point the cap recharges and floats. The design requires nothing more than a supercap and Schottky diode, as shown in Figure 9. The diode prevents the supercap from manhandling the USB port.

## OUTPUT TRANSFORMER RESISTANCE

**Q** I'm in the process of restoring a pair of 60-watt theater amps (Simplex AM-1026) and I have a concern about the output transformers. On one amp, the DC winding resistance of the primary is 75 ohms from B+ to one plate, and 75 ohms from B+ to the other plate: 150 ohms plate-to-plate. On the other amp, the corresponding readings are 75 ohms and 140 ohms, respectively, with 2, 215 ohms plate-to-plate!

My thinking is that if high voltage shorted some windings, shouldn't the resistance decrease? Otherwise, the 140

## MAILBAG

Dear TJ,

Regarding paging feedback to Dan Elliot in the January '06 column ... the device you suggested is good, and filtering bad frequencies is an answer if they are consistent. In our building, we've installed a delay to totally break the feedback loop with 100% success, and I would suggest Mr. Elliot use the delay element on the Shark unit before worrying about the notch filters.

— Greg

Dear TJ,

In the October '05 column, under "The Hounds of Baskervilles" (concerning the defecating dogs), to keep the next-door neighbors happy, I would recommend an environmentally friendly approach over the loud horn. How about an oscillating lawn sprinkler or two turned on by the existing sensors? I

don't think the dogs would be comfortable answering the call of nature with water streams pulsating around them. A junked washing machine would be a good source of electric water valves.

— Bud Fuechtmann

Dear TJ,

One thing you neglected to mention in the January '06 "Tube Amp Power Regulation" answer is to put a filter choke and bypass caps on the input to the filament regulator. In any switcher, noise will couple back to the power line through the transformer interwinding capacitance. It's easy enough to do — just cannibalize the parts from a busted ATX power supply. The first time I built a flyback switcher I knocked out every AM radio within a few hundred feet!

— Jack Walton  
Short Hills, NJ

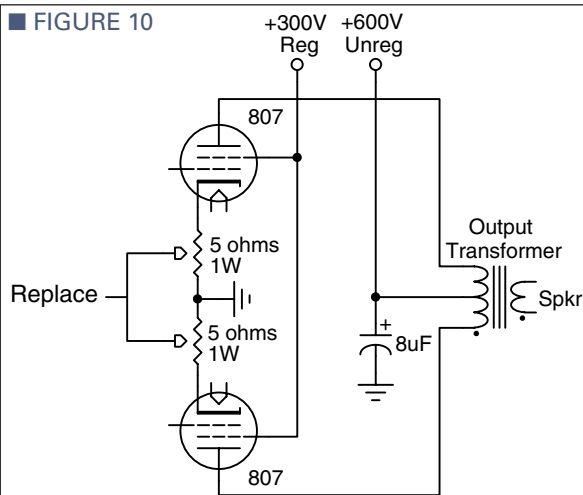


ohm reading may be correct and the other windings have shorted down to 75 ohms. My research shows that the plate-to-plate primary impedance is on the order of 5K. Which is it?

— John Agugliaro, CET

**A** The correct answer is 75 ohms. What happened is that one of the 807s shorted and sucked a lot of current through that winding of the transformer. This, in turn, raised the temperature of the wire considerably and destroyed the annealing of the copper wire. When copper gets hot, it often gains resistance, and can loosen solder joints. I doubt the turns are shorted on the other three windings. You might want to check out the five-ohm cathode resistor (Figure 10) on that leg, too. I'd bet it's fried. As

FIGURE 10



Typical Push-Pull Output

for the 5K impedance you mentioned, it is the inductive reactance of the coil measured at 1 kHz and has no relationship to DC resistance.

Now, about finding a new transformer — I suggest you look for one from a Hammond 1650 amplifier. They are easier to find than a Simplex origi-

nal and will perform the same — in fact, maybe a little better. That's because the Hammond transformer has taps for ultra-linear operation. That is, the screen voltage comes from one of the transformer taps. If you don't know how to do the upgrade, simply leave the ultra taps unconnected. **NV**

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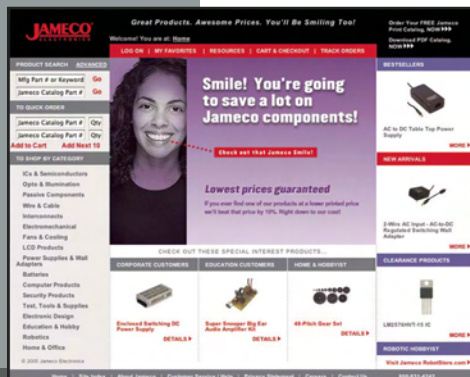
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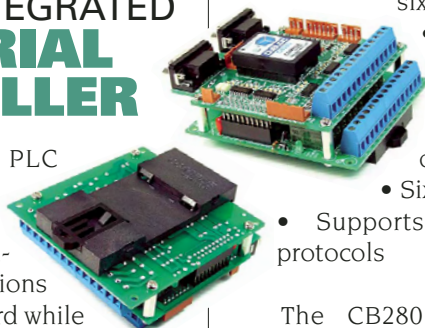
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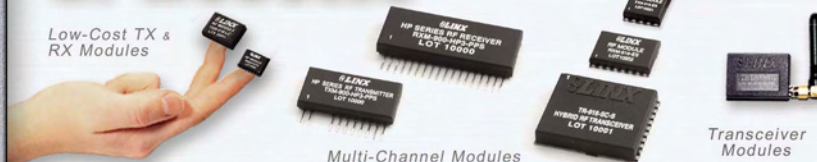
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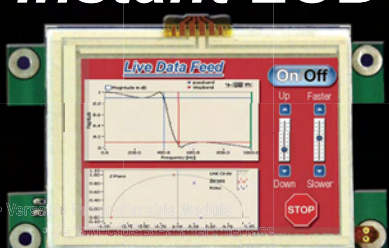
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\$110.25 + post & packing

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(Jameco #101258CC \$5.00)



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9VDC Wall adaptor required  
(Jameco #252751 \$12.05)



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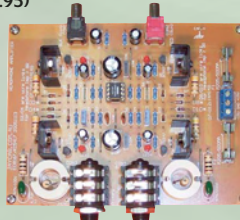


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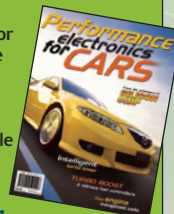
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## Independent Electronic Boost Controller

KC-5387 \$50.95 + post & packing

This can be used in cars fitted with factory electronic boost control using the factory control solenoid, or cars without electronic boost control using a solenoid from a wrecker etc. It has two different programmable boost curves and is programmed using the Handheld Digital Controller (KC-5386 \$37.95). Kit supplied with PCB, machined case, and all electronic components.

Suitable for EFI and engine management systems only.



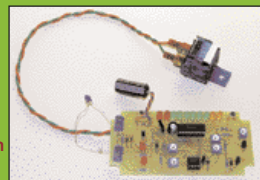
## Smart Fuel Mixture Display

KC-5374 \$17.95 + post & packing

This kit features auto dimming for night driving, emergency lean-out alarm, better circuit protection, and a 'dancing' display which operates when the ECU is operating in closed loop. Kit supplied with PCB and all electronic components.

Car must be fitted with air flow and EGO sensors (standard on all EFI systems) for full functionality.

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(HB-6014) \$2.55 each



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## ■ THIS MONTH'S PROJECTS

Octal Logic Probe .....	38
Pocket Marquee Badge .....	44
TheThereping .....	50

## ■ LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

- . . . . Beginner Level
- . . . . Intermediate Level
- . . . . Advanced Level
- . . . . Professional Level

**When prototyping with single chip computers like the PIC, SX, etc., it is often necessary to determine if multiple outputs are correct.**

**So, I created an octal logic probe that can be plugged directly into a prototyping socket to view eight adjacent pins at once. Several can be used to monitor the complete chip. Don't worry if one or two pins are analog or even tri-state, this probe won't mind and it won't affect your application either.**

# OCTAL LOGIC PROBE

## Design

As shown in the schematic of Figure 1, there are three basic sections to the logic probe: power, voltage reference, and the actual probe logic. The power section uses (in my case) a two-foot RCA cable filtered/bypassed by a capacitor on the board. The voltage reference section provides a common reference voltage of about 2V for all eight sections. Each individual probe is composed of a voltage comparator driving an LED with a current limiting resistor.

## Theory of Operation

The bypass capacitor is optional — I haven't needed it. You may need a small one to prevent noise from being transferred to/from the location being tested and the power source or even a larger one to filter the supply voltage due to the changing LED current and the quite long power

cable. The soldering pads are there, just in case.

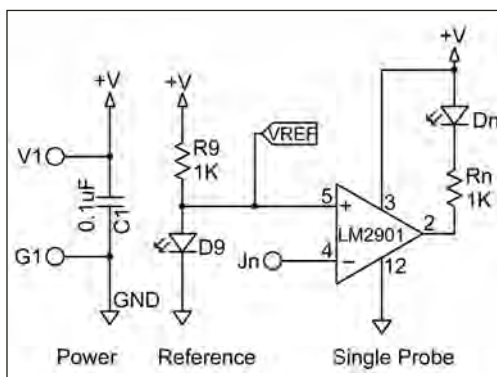
There is an important note on the "Input Common-Mode Voltage Range" parameter of the LM2901:

*Note 8: Positive excursions of input voltage may exceed the power supply level. As long as the other voltage remains within the common-mode range, the comparator will provide a proper output state. The low input voltage state must not be less than -0.3V DC (or 0.3V DC below the magnitude of the negative power supply, if used) (at 25°C).*

I interpret this to mean that the maximum difference between the two input pins where the output will still be correct is  $V_{DD} - 1.5V$ . Any larger and, though the comparator won't be damaged, it may not produce the correct output result. For a 5V supply, that means they can't be further apart than 3.5V. So, to make sure that the output is correct for all input values

from ground to +V, the reference voltage must be between 1.5V and +V - 1.5V.

An interesting property of most LEDs is that the voltage drop across them, when emitting, is nearly constant, regardless of current. In the case of green LEDs, it varied from around 1.9V at 3 mA to 2.1V at 16 mA. This is



■ FIGURE 1. The Basic Blocks.



well within the necessary common-mode voltage and is also a pretty good reference for TTL. This lets us have a (nearly) arbitrary supply voltage and, as a side benefit, we get a pilot light to indicate that power is applied and the probe is working.

The output of the voltage comparator is open collector to ground, with a current limit of (typically) 16 mA. It goes low when the negative input is higher than the positive input. A 1K ohm resistor, with a 2V drop across the LED, allows 3 mA at 5V, and 16 mA at 18V.

## Power Dissipation

One must always consider the power dissipation of ICs and other components. Basic LM2901 operation takes a maximum of 2.5 mA so with an 18V supply, that makes 45 mW. Each of the four output transistors drop 400 mV when saturated (on) and conducting 4 mA. Though it rises with higher current, even at the maximum of 16 mA we have only about 7 mW (rounding up is always a good idea) per output. The complete total is 73 mW, well under the 1,050 mW limit.

With the 1K resistor's minimum resistance (for 5% tolerance) of 950 ohms combined with the 1/4W rating ( $P=I^2R$ ,  $I=\text{SQRT}(P/R)$ ), we can have a maximum of 16.22 mA. With a voltage drop of 2.1V for the LED and 0.4V for the output transistor, the maximum allowable supply voltage is 17.9V to keep within the resistor's power rating. Now the output transistor's voltage drop goes up with higher current, but we don't have a specification of how much, and 16.22 mA is a little larger than it can take, so let's be safe and keep to a maximum supply of 17V.

All these specifications assume that the IC is at 25°C (77°F), which is mostly valid since we haven't put it in any sort of box and air can flow freely around both ICs.

■ **FIGURE 2. Power Distribution Block.**

## Design Variations

As I have built them, the probes are for monitoring TTL (and related families) and can be powered from nearly any supply. If you wish to work with CMOS, a better variation would be to replace R9 and D9 with 3K and 2K ohm resistors, respectively. The threshold would then vary with supply voltage and would fall somewhere in between the typical CMOS values, but you will then have to power the probe with the same (voltage) supply as the circuit under test.

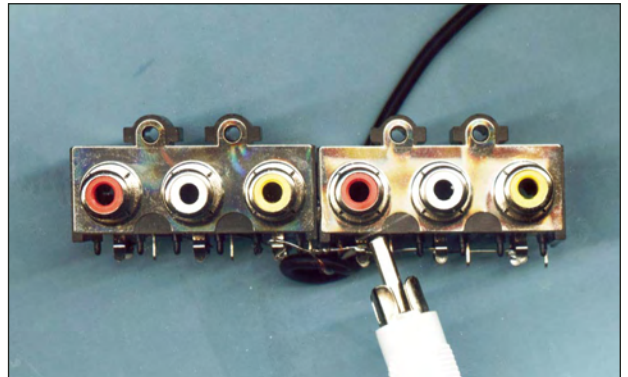
Equal valued resistors would probably be best for monitoring 3.3V logic (remember the common-mode voltage above). The LM2901 will work down to 2V, but the LEDs won't ... at 3.3V and less than 1 mA, the LEDs may be a little dim.

## Power Distribution

There are many ways to bring power to the probe. Since we are dealing with prototyping sockets, one could use a length of two-conductor ribbon cable with two pins soldered to one end that would then be plugged into the socket. This works well, except that you have to remember to get the the polarity right each time you set it up.

I chose to make a power distribution block from several of the ganged RCA jacks like you see at the back of VCRs and TVs. I then wired it permanently to my power supply and

■ **FIGURE 3. Slicing a Cable.**



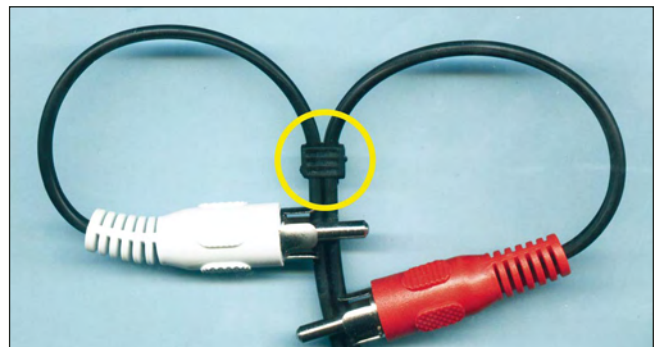
mounted it next to the prototyping socket. The probe's power cable ends in an RCA plug that makes it easy to power it up.

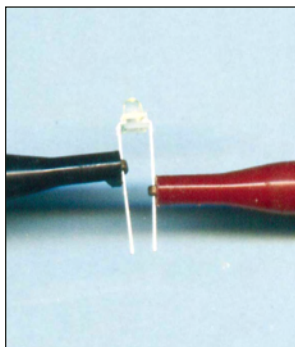
In the future, I intend to make other kinds of modules that contain common blocks of logic (RS232 plus DB9) and/or other test gear (debounced push buttons) and they can use the same power panel.

## Parts Availability and Substitutions

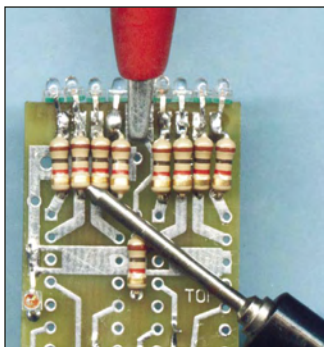
If you can't find an LM2901, the LM339 or any other member of that family will do. Even other quad voltage comparators — just make sure you check the pin-outs and adjust the PCB board, if necessary, and redo the calculations above for voltage limits, etc.

I actually obtained six-foot stereo RCA cables and the gang jacks at my local HSC store ([www.halted.com](http://www.halted.com)) and expect that they are available in other surplus stores or on sale at various retail stores. The cables I found had a little blob of

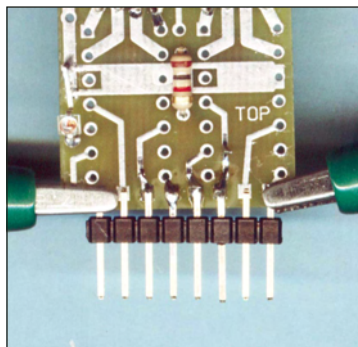




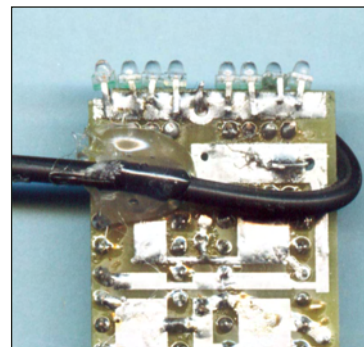
■ **FIGURE 4.** Testing LED Polarity.



■ **FIGURE 5.** Testing Your Work.



■ **FIGURE 6.** Header Attachment.



■ **FIGURE 7.** Hot Glue Strain Relief.

plastic (see Figure 3) at each end that kept them from coming apart and, once that was cut off with a pair of scissors, it was easy to separate them into mono cables, and then cut two feet from each end.

I discovered they weren't actually shielded and the ground wire was a little delicate to work with, but I ended up with four two-foot power cords for less than \$1.

The rest of the parts are from Jameco ([www.jameco.com](http://www.jameco.com)). If you substitute LEDs, make sure you get small ones (T 3/4) and verify the voltage drop for various currents to redo the design computations above, if necessary.

Since it has a much better price per pin, I bought the 17 pin headers (SMH17 = Jameco #103376CX) and cut off two eight-pin sections.

Double-sided, plated through, solder coated circuit boards are available from my store (<http://ImpossibleEnterprises.com/>) for \$6.50 each or with a kit of parts for \$9.50. Prices and availability may vary.

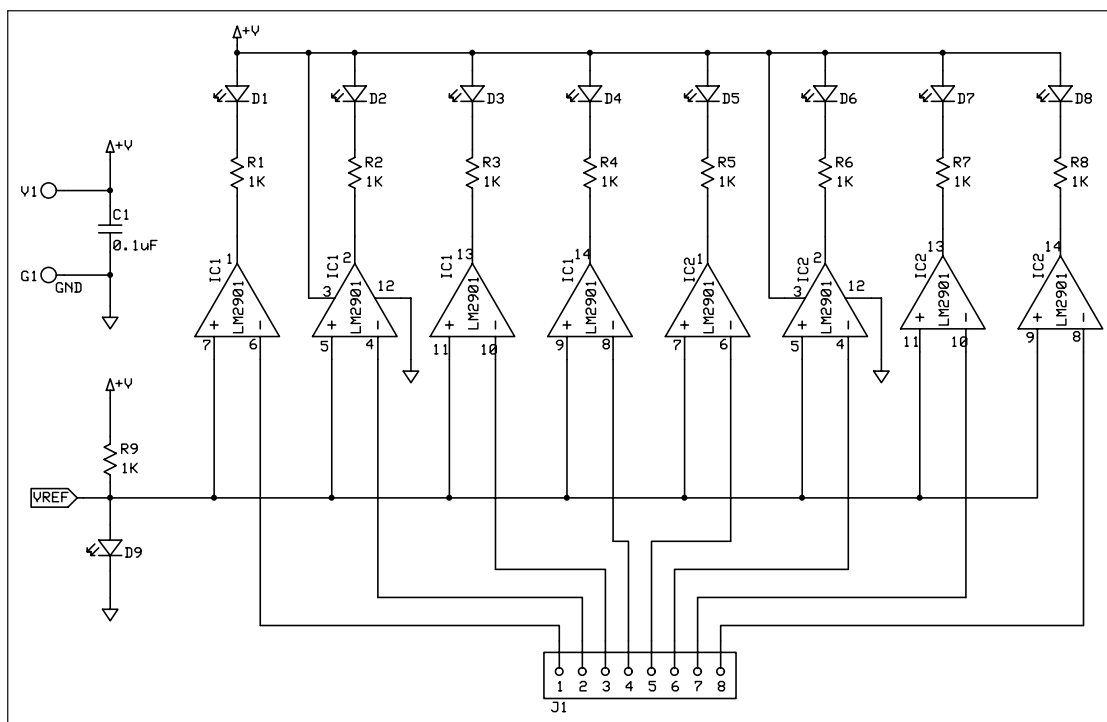
## PC Board

I used software from ExpressPCB ([www.expresspcb.com](http://www.expresspcb.com)) to lay out the schematics and board and their service to manufacture them. Please note that the bottom

copper is still viewed from the top, and will need to be reversed left-to-right if you are making your own boards. A dremel-like tool with a thin cutting disk was used to saw the large PCB into individual modules. All of the design files are available on the *Nuts & Volts* website ([www.nutsvolts.com](http://www.nutsvolts.com)), as well as in my store.

The gain on these devices is incredible. When near the threshold voltage, a very small voltage change will make a very large change in the output, but inverted. Unintentional feedback can lead to oscillation, so there must be shielding between the input and output sections of

these devices. For the most part, this isn't much of a problem here, as it's just us humans who are watching the LEDs and we'll never notice if they flicker when a pin is driven really near 2V (the reference voltage). But, it may be the case that a really strong oscillation will generate a signal in the power leads or even back down into the circuit under test so, in the layout, I tried to get a band of ground between the inputs



■ **FIGURE 8.** The Entire Octal Logic Probe.



## PARTS LIST

QTY.	PART NO.	DESCRIPTION	MSRP	SOURCE
□ *1		PC Board	\$6.50	Impossible Enterprises
□ *2	LM2901N	Quad Voltage Comparator	26¢	Jameco 23296CX (or 246537CX)
□ *9	MV50G	Green LED T 3/4	12¢	Jameco 176532CX
□ *9		1K 1/4W 5% Resistor	1¢	Jameco 29663CX
□ *1	SMH08/SMH17	Eight position single row header .1"	20¢/16¢	Jameco 153701CX (or 1/2 103376CX)
□ *1/4		Six foot stereo RCA audio cable	\$1.79	Like Jameco 228451CX (see text)
□ 1		0.1µF 25V Mylar Capacitor	11¢	Jameco 135562CX
□ 1+		2 x 3 grid RCA block	89¢	Like Jameco 237016CX (see text)
□ 1		Full kit of all marked (*) parts	\$9.50	Impossible Enterprises

and outputs, on both sides of the board.

A couple of hints on PCB design: It is always a good idea to label either the top or bottom of the board, especially when you don't have a silkscreen. It is also a good idea to mark the board with a version number so that if you have any spares left over, you will know just which layout you have when you find them years from now — hence the "TOP" and "JSB 2.0" bits of text on the top copper layer.

## Construction

**Step 1:** Solder the top row of LEDs. This is the tricky part. Note how the LEDs straddle the edge of the PC board and are soldered to pads rather than inserted through holes. Though one LED lead is slightly longer than the other to indicate polarity, I find it easier to just test it with a power source and current limiting resistor, especially after having trimmed the leads and then dropping it on the bench. Get their polarity right — cathodes on the front, anodes to the back. I didn't get this right the first time and it was a chore to unsolder and reverse them. There is just enough room for each T 3/4 sized LED packed edge-to-edge, so start in the middle of each group of four, then do each adjacent one, and then the final one. Position one, then note how much wire needs to be cut off. Trim it by holding it in place with your finger and tacking

the front lead using the solder that's already on the board. Solder the back and then resolder the front lead (see Figure 4).

**Step 2:** Solder all resistors and D9. Watch out for the polarity once again. Work from the middle of each quad out, like the LEDs. A pair of toe-nail clippers makes a great tool to trim the leads after soldering.

**Step 3:** Test what you've got so far. Rig up a power supply and a couple of alligator clips. Place a 200 ohm resistor in series just to make sure any shorts won't cause trouble. Clip the plus lead to the center area between the LED groups and the negative lead to one end of a voltmeter probe. Touch the probe to ground; the pilot light should light. Touch the probe to each of the eight resistors; exactly one LED should light. If one does not, check the solder joints and the LED polarity. If more than one does, look for solder bridges (see Figure 5).

**Step 4:** Cut and attach the header. Not too close — remember to leave a little room for the IC pins. Use 'gator clips to hold the edges and solder some center pins, then remove the clips and finish the job (see Figure 6).

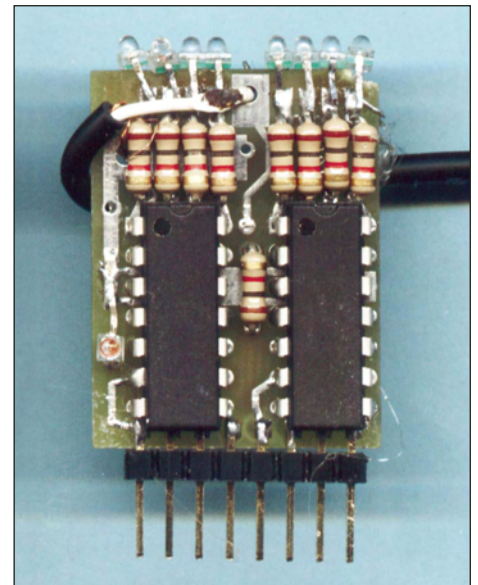
**Step 5:** It's time to add the ICs. Make sure that pin 1 is nearest to the LEDs. Alternate soldering between the two ICs to give them a chance

to cool down.

**Step 6:** Strip and solder the power cable to the designated holes. The center conductor should be +V; the hole between the LEDs. The shield goes in the hole on the left just below the LEDs. Insert both from the front, then bend the cable around to the back and use a blob of hot melt glue to anchor it to the back of the board (see Figure 7).

**Step 7:** Build your power distribution panel by connecting the center terminals of all the RCA jacks together. Typically, all blocks have the ground (outer) connector already in common. Add a cable from it to your power supply. Keep the center lead

■ **FIGURE 9.** The Octal Logic Probe.





connected to +V.

## Capabilities

So now you have one, just what can it do? It can be powered from any DC source between 5V and 17V, even a 9V battery. Just make sure the ground is common with the circuit under examination. It draws a maximum of 149 mA at 18V or just 32 mA

at 5V. Each input has a threshold of around 2V regardless of supply voltage, which is acceptable for TTL and okay for CMOS designs. It may be good for monitoring 3.3V designs, as well when powered with 5V or more. The inputs will not be damaged by any POSITIVE voltage up to 36V, regardless of supply.

With the extremely high input impedance, each input draws 250 nA

(yup, nanoamps), so they won't add any loads to your logic. The boards are only a little bit wider than the eight locations that they are monitoring so you can — by staggering them a little — plug in as many as you need to watch a wider bus or more output ports. They are symmetrical so flip them around to make more room.

## Restrictions

Okay, so what's the bad news? Well, the inputs are not protected against NEGATIVE voltages. Any value less than 0.3V below ground can possibly fry the input section of the chip and/or the source of the signal. With the threshold of 2V, it is theoretically possible that your TTL or CMOS circuit will see an *intermediate* voltage as a one while this probe displays a zero, or vice versa.

## What Would I Change?

Now that I've made them, what would I redesign? I think I might try using surface mount ICs to make the boards just a little narrower so that you could really stack them end to end. This would also leave more room for a 10K resistor on each input to limit the current drawn when faced with negative voltage.

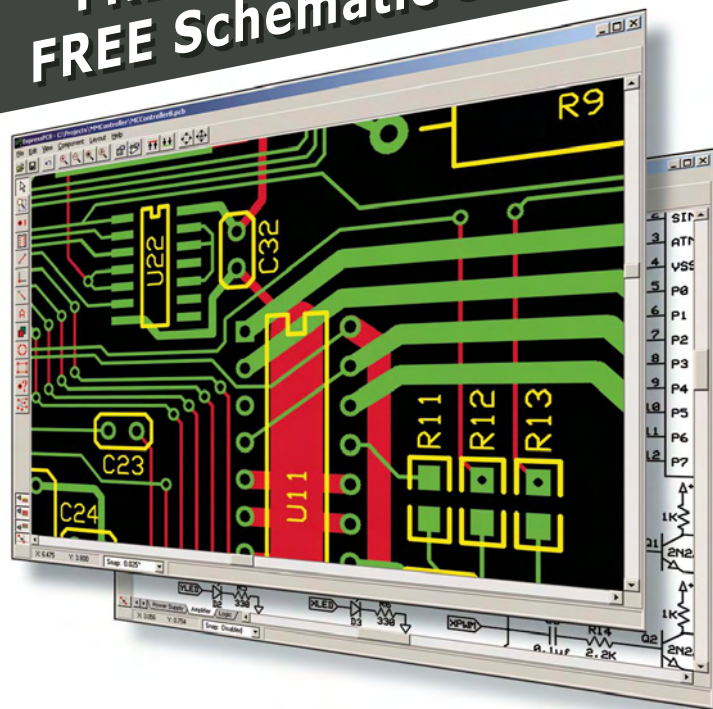
I may change the next version of the PCB to move the LEDs and resistors just a little bit further apart.

Perhaps some way to alter — automatically or manually — the threshold so that it can be more useful with CMOS, and at 3.3V and below are options, as well.

## Conclusion

Well, there you have it — a simple, basically cheap, built-in-an-afternoon and useable-for-the-rest-of-your-prototyping-days octal logic probe. Make a bunch, you'll need them eventually. **NV**

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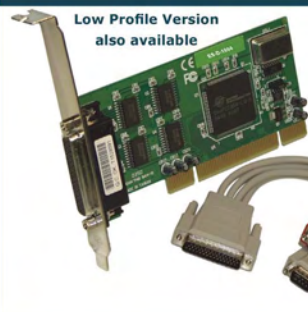
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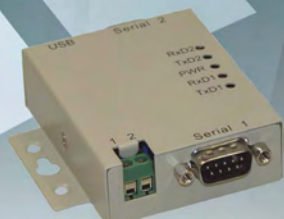
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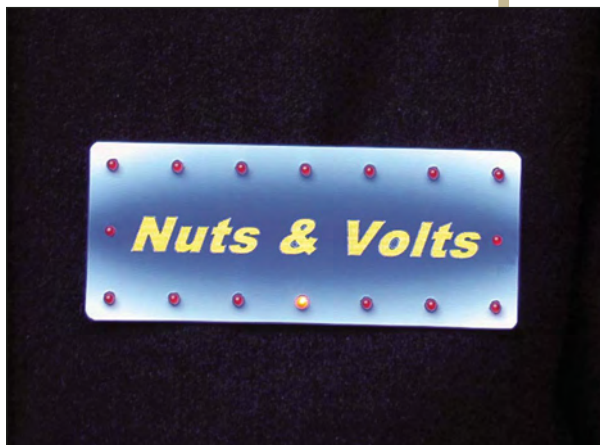




**The Pocket Marquee Badge is an easy-to-build construction project for anyone looking for an attention-getter to take to conventions, meetings, or parties.**

**As shown in Figure 1, it consists of a 1.8"H x 4.4"W circuit board with 16 red LEDs mounted around the perimeter. One LED lights at a time, in sequence, and gives the illusion of motion similar to the lights seen on a theater marquee. A 1.25" x 3.5" space, surrounded by the LEDs, is available for you to mount a standard size engraved name tag, sales slogan, etc. Alternatively, you can make your own tag using your computer and printer.**

■ **FIGURE 1.** Photo of the Pocket Marquee Badge with computer printed label. The badge is pinned into place on a sweater, jacket, etc.



# **BUILD THE POCKET MARQUEE BADGE**

**T**he Pocket Marquee Badge is attached to your shirt or coat pocket by using a 'pin back' available at fabric or craft stores. All components are SMT and are placed on the side opposite the name tag. Power is obtained from a small coin cell battery that will run the device in excess of 10 hours of continuous use.

While this project is not complex, it did require consideration of a few tradeoffs during the design phase. I'll go through some of these factors in the hope that it will help you with your own designs and also give some insight into how a design can evolve over the years.

The origin of this project actually goes back many years to the late 1970s. During that time, Low Power Shottky (74LS) logic devices were king. I designed the original Pocket Marquee Badge as an eye-catcher for salesmen in a trade show booth; 74LS parts were used and the schematic is shown in Figure 2. At that time, LEDs weren't nearly as efficient as today's devices, and at least 10 mA of current was needed to get reasonable brightness. The 74LS parts were real power hogs compared to modern CMOS chips and

when coupled with the low efficiency LEDs meant that an alkaline 9V battery only lasted about six hours.

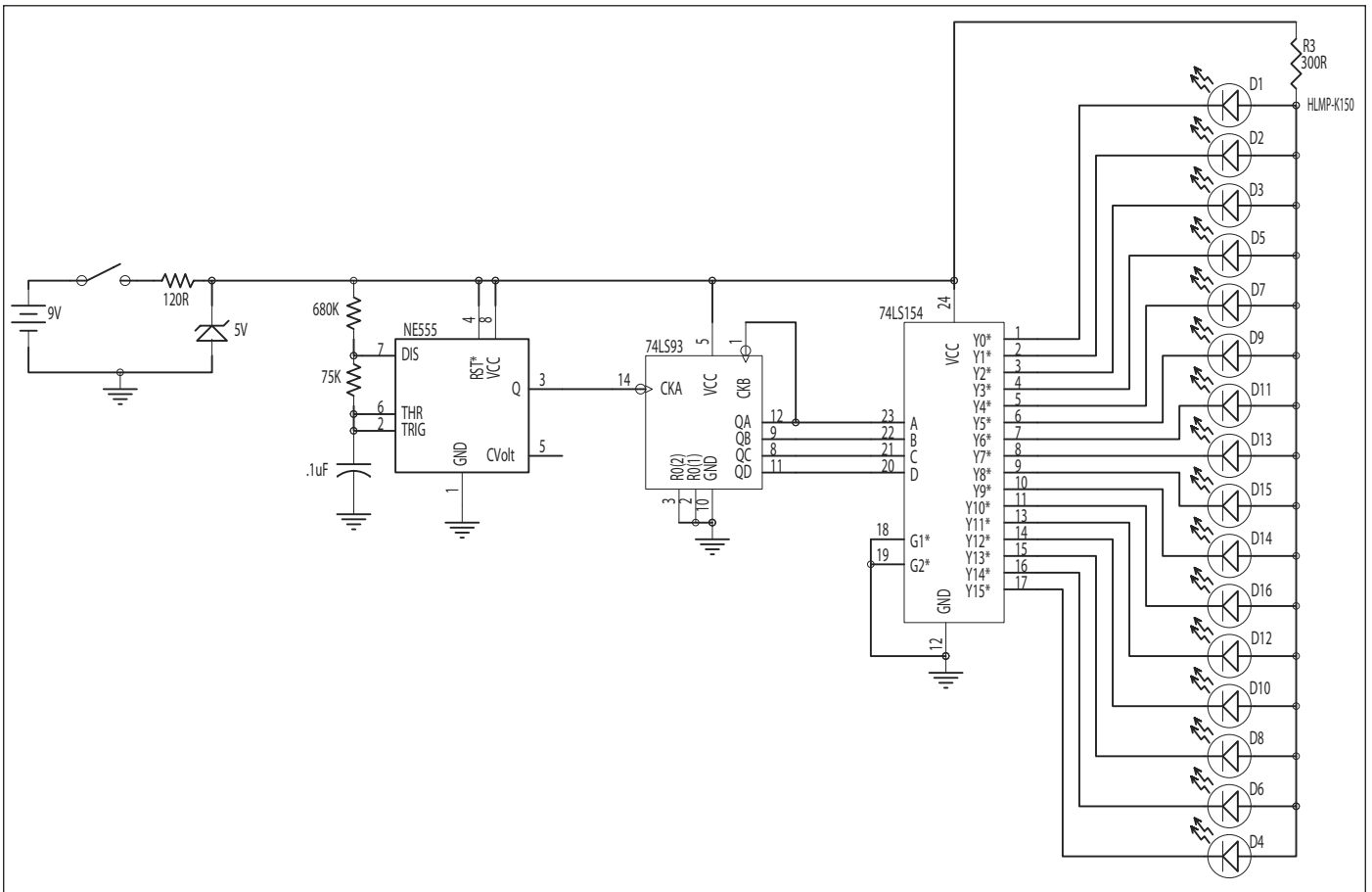
While recently cleaning my office, I found one of these 25-year-old gadgets and thought it would be an interesting project to redesign it using more up-to-date technology. The shortcomings of the old design included off-board components such as an on/off switch, large battery, and the associated wires. Also, the run-time from a new battery was barely adequate. Lastly, it was expensive to replace the battery.

## **Circuit Description**

Figure 3 shows the results of the redesign and how the previous shortcomings were addressed. The LEDs are low current devices that produce plenty of light at 1 mA. HC logic ICs are used to keep current drain to a minimum. The pushbutton switch — S1 — is soldered to the PCB and is briefly pushed once to start the marquee display and pushed again to stop it. U3C is an oscillator running at approximately 15 Hz with each pulse at U3-8 incrementing the binary counter, U1, by one. U3D and U3B form a flip-flop that is set and reset by S1.

The LEDs are in motion when U3-11 is high and U3-6 is low and





■ **FIGURE 2. Original Pocket Marquee design from the 1970s.**

conversely, the oscillator is disabled when U3-11 is low and the decoder is disabled when U3B is high. The binary sequence appearing at U1's outputs are decoded by U2, which is a four-line to 16-line decoder. As the counter increments from 0000 to 1111, U2 outputs Y0 through Y15 sequentially (and individually) go low. A low output from the decoder causes current to flow through the selected LED causing it to light up until the next pulse from the oscillator.

The circuitry is powered by a low cost 3V Lithium coin cell. With a fresh battery, the current drain is approximately 1.1 mA and with the specified 48 mAH battery you might expect the battery to last  $48/1.5 = 32$  hours. Unfortunately, this figure is a bit optimistic for two reasons. First, if you look at the data sheet for the CR1225 battery you will see that it is rated at 48 mAH if the discharge current is 100  $\mu$ A, and only 33.6 mAH if the discharge

current is 1 mA. Secondly, the capacity of the battery is determined when the battery is discharged down to 2.0 V.

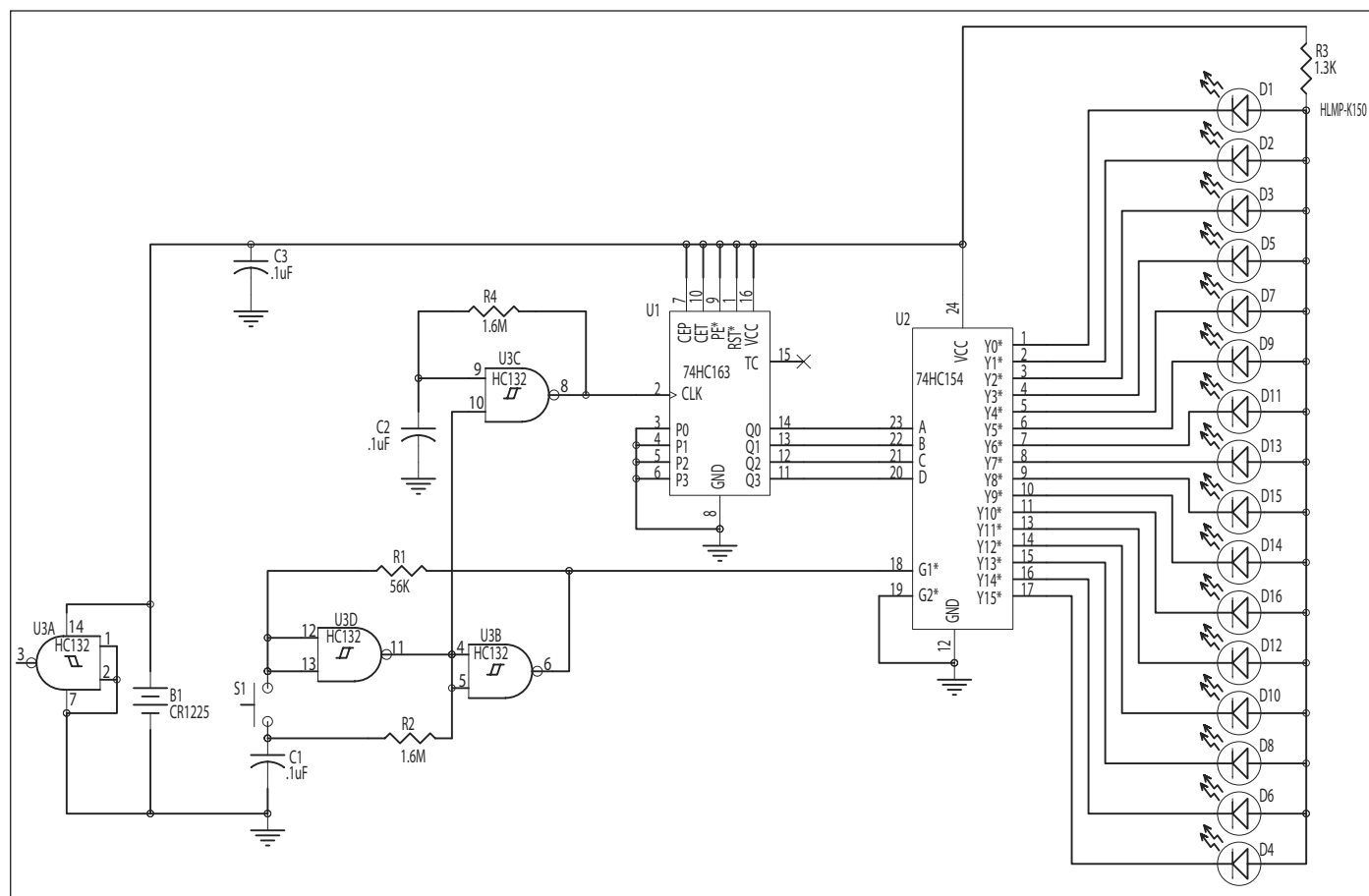
At this point, the ICs still function, but the LEDs are quite dim. So, the net effect of these two factors is that you will probably get somewhere around 10-12 hours of continuous operation before you will want to change the battery. Depending on where you purchase the battery, it should cost less than \$1, which results in a per-hour cost of less than 10 cents.

Since pushbutton switch S1 doesn't ever actually remove power from the circuitry, the ICs always have battery voltage applied. Fortunately, only leakage currents flow when the circuitry is in the disabled (LEDs off) state. I measured a battery drain of approximately 10  $\mu$ A in the prototype which means that the battery will be discharged in approximately five months, even if the LEDs are not lit.

The bottom line is this: If you aren't going to use the Marquee Badge for a while, just pop the battery out of the holder, turn it around so the positive end is facing down towards the PCB, and put it back into the holder. The design of the holder is such that when the battery is installed reverse-polarity (backwards), no contact is made to the positive terminal which means no harm to the battery (or the circuitry). This provides for a convenient way to store the battery for extended periods with losing it!

If you want to speed up or slow down the 'motion' of the LEDs, just decrease or increase, respectively, the value of R4.

Increasing the value of R3 will make the battery last longer but the LEDs will be dimmer. If you are in a brightly lit area and want the LEDs to be more visible, decrease the value of



■ **FIGURE 3. New, low power version of the Pocket Marquee badge schematic.**

R3. Values much below 910 ohms are not recommended due to significantly reduced battery life.

There are two types of commonly available pin backs: adhesive and non-adhesive backed. If you obtain the adhesive-backed type, it is an easy task to place it in the top center of the PCB, as shown in Figure 4. Otherwise, you

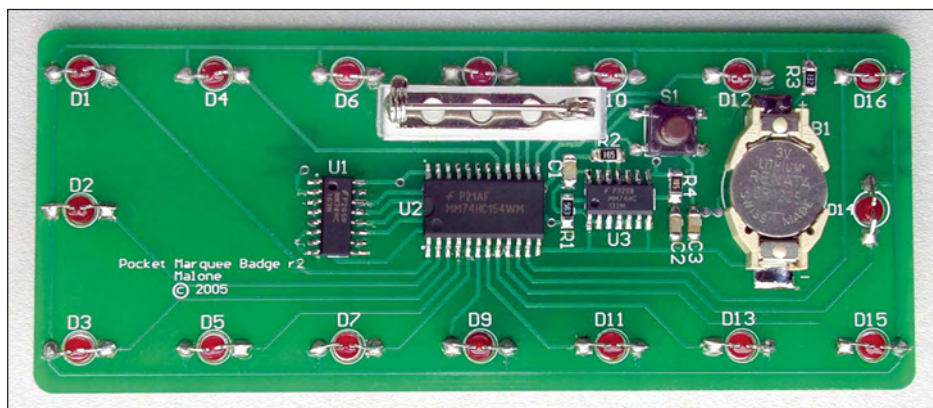
will have to glue the pin back into place.

## Assembly

You can certainly hand-wire the Marquee Badge, but a circuit board makes the assembly process much easier and neater. The circuit board can also be used as a template for making your own name tag. If you decide to make your own tag, do so before putting any parts on the circuit board.

After you have designed your name tag using your word processor or graphics layout program, print it and then place the circuit board on the back side of the name tag. Mark the perimeter of the tag and LED holes with a sharp pencil. Use scissors to cut out the tag and a sharp hobby knife to cut circular holes for the LEDs to protrude through. A paper-glue stick can be used to attach the name tag to the circuit board. You may also want to coat the tag with a protective spray, such as Krylon.

The ICs for this project were intentionally chosen because they have relatively large lead spacing (0.050") to make soldering easier. Even still, you will need a fine tip on your soldering iron to avoid shorting adjacent pins



■ **FIGURE 4. Component location is shown in this photo. Note the trace around the perimeter of the PCB that connects to all of the LED anodes. Also shown is the suggested location for the pin back.**



## Build the Pocket Marquee Badge

together with solder. Use standard anti-static precautions when handling the ICs prior to their being soldered onto the PCB (grounded wrist strap and grounded anti-static work surface).

Solder resistors, capacitors, and battery holder first, ICs second, and LEDs last. Before soldering the battery holder in place, make sure that the + on the holder is oriented properly with the + on the circuit board silkscreen. If the holder is installed backwards, something is going to get damaged!

When installing the LEDs, be sure to align the anode and cathode leads with the proper pads on the circuit board. Note that the anode lead on the LEDs is longer than the cathode. Another way to distinguish between the anode and cathode is to use the diode test function on your DMM. When the LED is lit, the positive lead is connected to the anode. Bend LED leads at right angles to the body and trim excess lead length, as shown in Figure 4.

After component assembly is complete, inspect all of the solder connections for shorts, cold solder joints, etc. Next, install the battery with the negative side down towards the circuit board. If the LEDs don't start sequencing on their own, briefly push the on/off switch. After the circuit is functioning normally, remove the battery and attach the pin-back. You may want to apply a protective coating of spray varnish to the completed assembly. If so, don't forget to first mask off the switch and battery with tape.

### Additional Thoughts

An obvious alternative to the logic IC design described in this article is to use a microcontroller, such as a PIC. The use of a microcontroller would make the generation of much more interesting and complex patterns of moving lights possible. However, most — if not all — of these patterns would involve more than one LED lit at a time. This results in increased current drain and shortened battery life. If this is an acceptable trade-off, then this may be an avenue for you to explore.

LED jewelry and other novelty

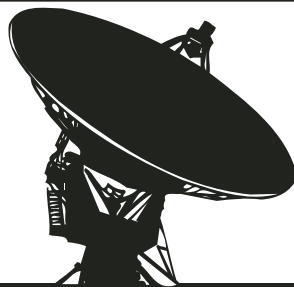
## PARTS LIST

The parts listed here are appropriately sized to fit on the printed circuit board used in the author's prototype and also available as listed below. Obviously, if you decide to hand-wire your Pocket Marquee Badge, you have more latitude in choosing what parts to use. Please note that all parts listed below are supplied from Mouser, unless noted otherwise.

ITEM	DESCRIPTION	PART NO.
<input type="checkbox"/> B1	Renata CR1225 3V Lithium coin cell	614-CR1225
<input type="checkbox"/> C1, C2, C3	0.1 $\mu$ F 1206 SMT capacitor	140-CC502B104K
<input type="checkbox"/> D1-D16	Agilent HLMP-K150 red LED	512-HLMPK150
<input type="checkbox"/> R1	56K 1206 SMT resistor	263-56K
<input type="checkbox"/> R2	1.6M 1206 SMT resistor	263-1.6M
<input type="checkbox"/> R3	1.3K 1206 SMT resistor	263-1.3K
<input type="checkbox"/> R4	1M 1206 SMT resistor	263-1M
<input type="checkbox"/> S1	Mountain Switch 101-0364 tactile pushbutton switch	101-0364
<input type="checkbox"/> U1	74HC163M	512-MM74HC163M
<input type="checkbox"/> U2	74HC154M	512-MM74HC154WM
<input type="checkbox"/> U3	74HC132M	512-MM74HC132M
<input type="checkbox"/> Battery holder	Renata SMTU1225-1	614-SMTU1225-1
<input type="checkbox"/> Pin-back adhesive backed available at fabric stores.		
<input type="checkbox"/> Etched, drilled circuit board with solder-mask, and silkscreen available from Doug Malone, P.O. Box 1542, Battle Ground, WA 98604 for \$12 plus \$4 shipping/handling.		

items are becoming more and more popular. However, the Pocket Marquee Badge is special for two

reasons: you can use your creativity to customize the tag to suit your needs and you build it yourself! **NV**



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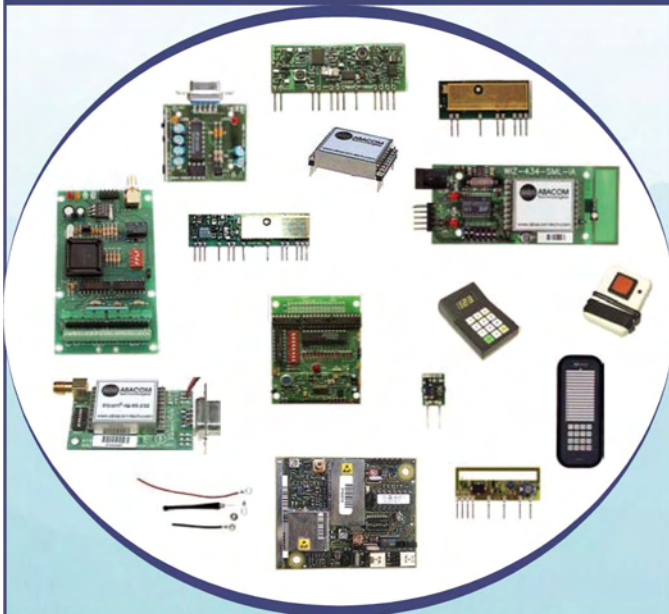
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# THE CREATION OF THE THEREPING

## In the Beginning

The quest for a new and interesting musical instrument began when The Robot Group (an Austin, TX-based Robotics, Art, and Technology club) was selected to participate in the First Night Austin celebration with a proposal they entitled “The Robot Theremin Band.” The idea was to use theremins (see sidebar: “What’s a Theremin?”) and robots together to create an experimental, musical spectacle. However, the Theremin is a difficult instrument to play *well* as it requires a high degree of accurate physical control (i.e., hand/body position), as well as a good knowledge of music theory. As far as expertise is concerned, it has much in common with a violin in that, if played well, it

can be beautiful. If *not* played well, it can be ... unpleasant at best.

After reading a description of the proposal on The Robot Group’s mailing list, I posted that “a group of technically minded folks, with no musical training, trying to play Theremins would sound roughly like someone attempting to murder a large number of cats with a mallet.” Since this might be more apt to repel people than attract them, I suggested we consider crafting some sort of electronic musical instrument instead.

## Ahhhhh ... FREQ OUT!

In mid November 2005, at a meeting held at my house, Don Colbath (one of the group members who actually owns a real

## WHAT’S A THEREMIN?

■ The Theremin or Thereminvox is one of the earliest fully electronic musical instruments. Invented in 1919 by Russian Léon Theremin, the Theremin is unique in that it requires no physical contact in order to produce music and was, in fact, the first musical instrument designed to be played without being touched.

The instrument consists of a box with two projecting antennas around which the user moves his or her hands to play. To control the Theremin, the musician stands in front of the instrument and moves his or her hands in the proximity of two metal antennas — the distance from the antennas determining frequency (pitch) and amplitude (volume).

Small movements of the hands can create a

tremolo or vibrato effect. Typically, the right hand controls the pitch and the left hand is used for the volume, although some play left-handed.

Based on the principle of heterodyning oscillators, the Theremin generates an audio signal by combining two different — but very high — frequency radio signals. The capacitance of the human body close to the antennas causes pitch changes in the audio signal, in much the same way that a person moving about a room can affect television or radio reception.

By changing the position of the hands relative to the vertical antenna, a performer can control the frequency of the output signal. Similarly, the amplitude of the signal can be affected by altering the hand’s proximity to the looped antenna. *The information above is excerpted from “Wikipedia,” located at [www.wikipedia.org](http://www.wikipedia.org)*





■ **FIGURE 1.** PING)))™ Sensor. The Parallax PING))) sensor uses ultrasonic soundwaves to determine the distance to an object and returns a value in milliseconds that is quite accurate. It only requires three connections: 5V+, GND, and a single TTL level pin for both sending and receiving data.

Theremin) was toying with a small test system I was using to demonstrate the Parallax BASIC Stamp II connected to a Parallax PING)))™ sonar sensor (Figure 1). The test system was running a program that would show the distance of an object from the PING))) sensor on an LCD display. Don remarked that if the distance reading could somehow be sent to an audio oscillator, it might be possible to make a sound similar to a Theremin!

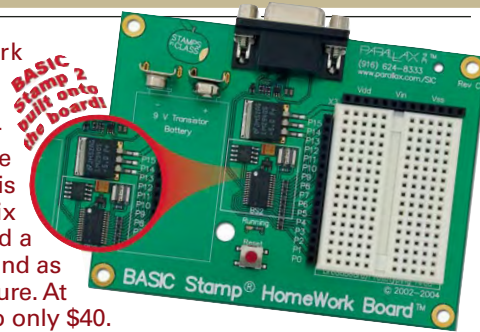
Intigued, I wrote some very simple PBASIC code that would measure the distance reported by the sonar sensor and store it in a variable. Then, rather than try to cobble together an oscillator, I just stuffed that value into the PBASIC command used to create sounds (the aptly named `FREQOUT`) to have the BASIC Stamp itself produce sound directly as shown below.

```
PING    PIN 4    \ Parallax PING)))
SPEAKER PIN 9    \ Speaker
SAMPLE VAR Word \ Store result
```

```
AGAIN:
  PULSOUT PING, 5
  PULSIN PING, 1, sample
  FREQOUT SPEAKER, 100, sample
  GOTO AGAIN
```

When we ran the code, the unit began to play sounds at a pitch in proportion to the distance of your hand to the PING))) sensor! A new musical instrument, the “Thereping” was born!

■ **FIGURE 2.** The Parallax HomeWork board. These are self-contained BASIC Stamp II microcontrollers with a built-in breadboard and DB9 serial interface for programming. The HomeWork boards are only sold in a 10 or 20 piece pack, but this would give us enough units to have six instruments, one master sync clock, and a few spares to use for experimentation and as backups in the event of a component failure. At quantity 10, the per-board price drops to only \$40.



## Parts is Parts

Now that we had a proof of concept, it was time to fabricate a bunch of instruments. Denise Scioli, a member of the The Robot Group, agreed to contact Parallax and order all the parts we needed. Since the prototype instrument was based around the BASIC Stamp II microcontroller from Parallax, and we planned to build six instruments, we decided on the Parallax HomeWork Board (Figure 2) to act as the base, as it's available in 10-packs, at a good price.

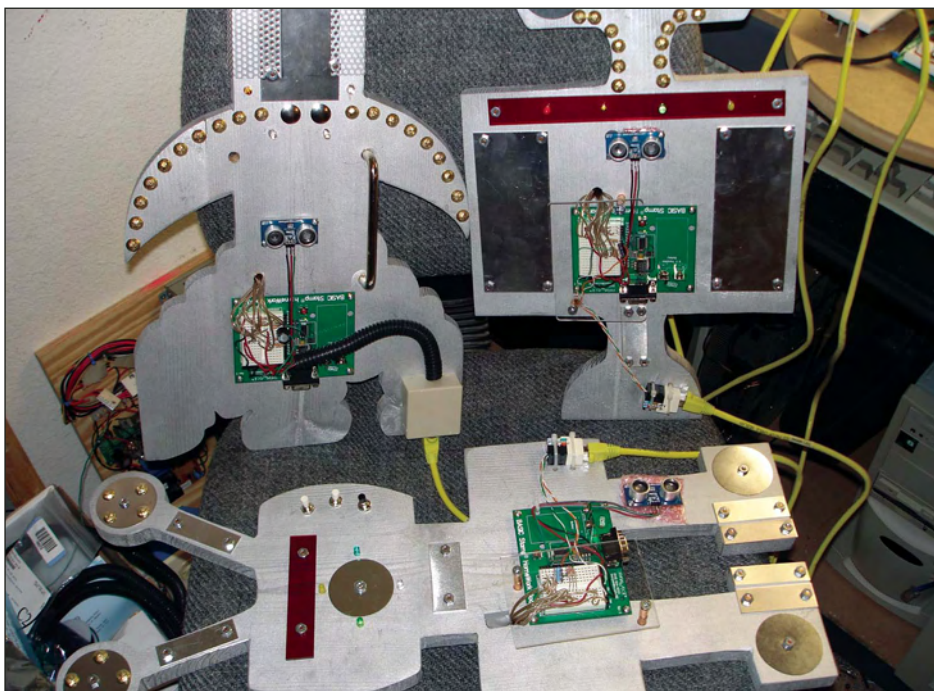
Denise placed the order and soon we were in possession of 10 HomeWork boards and 10 PING))) sonar sensors. In preparation for the project, Denise also created and deco-

rated some wooden cutouts (Figure 3) in fanciful shapes of rocket ships and robots that were to be used as a base to hold the HomeWork boards and provide a familiar playing paradigm (i.e., “guitar like”). I attached one of the HomeWork boards and a PING))) sensor to one of the boards to get an idea for how the instrument would look and feel.

## Refining the Idea

Though we had one prototype circuit and mount for our fledgling Thereping — and this prototype would make sound — it was not necessarily a *pleasant* sound. Also, like an actual Theremin, it required

■ **FIGURE 3.** Three Therepings.





some skill in music and physical control to create consistent musical notes and/or melodies. More importantly, if we built a number of these units, they would suffer the same weakness from which a group of “real” Theremins would have suffered (i.e., the “malleted felines” syndrome).

We needed the ability to place musically “unskilled” folks into the role of “musician.” With just under six weeks left, the problem was broken down into pieces to solve one at a time.

## What Can Go Wrong?

For our purposes, there are two fundamental things that you can do wrong when playing an instrument:

1. You could play an incorrect note.
2. You could play a note at the wrong time.

The “incorrect note” issue was attacked first. Since there are scales in which any of the notes, when played together, will sound correct, I conducted an experiment using a blues scale in the key of C.

On the prototype instrument, I created code that would instruct the PING))) sensor to fetch a distance reading, then check the returned reading against a range of values to determine what note should be played. The first code looked like that in Listing 1.

Though not very efficient, this code did “brute-force” determine the hand distance above the sonar sensor and then make it so the instrument would only play corresponding notes that would be valid in the blues scale. When this code is run, you can move your hand above the sensor and the note that corresponds with your hand position is played. However, the timing between the notes is fixed at 100 ms (roughly 16 notes at 120 bps) and your hand position is absolute (i.e., you cannot change the distance your hand must travel to create specific notes).

At the next meeting of The Robot Group, Eric Lundquist — another long-time group member (and programmer by trade) — had some great ideas to optimize the program. We refined the code in a number of ways to

make the instrument more efficient and flexible.

First, we broke the space above the PING))) sensor into discrete “zones” that could be calibrated to make the sensing area adjustable and allow the notes to be scaled to different octaves or pitches. This was accomplished by determining the highest and lowest PING))) sensor readings in milliseconds acquired while comfortably moving our hand over the sensor (from a bit less than one inch to about eight inches) and setting those values into constants:

```
LOWPos    CON 100    ` MS Value for closest note
HIGHPos   CON 800    ` MS Value for furthest note
```

Then, we set a constant to hold the number of notes into which we wanted the range divided:

```
NNotes CON 7 ` Number of notes in the scale
```

This divided the airspace above the sensor into seven one-inch zones. Now you could tell in which zone the user's hand was detected by using the simple formula:

$$\text{Zone} = (\text{HighPos} - \text{LowPos}) / \text{NNotes}$$

In order to make the code easier to read and more intuitive, I used the PBASIC CON command to create an “alias” of the Hz values for each note in a 12-note chromatic scale. This alias would reflect the note's “name,” its modifier (sharp or flat), and the octave. The naming convention I chose was:

**<note letter><sharp/natural><octave>**

For example, the notes from C6 through C7 would look like:

```
Cn6  CON 1047
Cs6  CON 1109
Dn6  CON 1175
Ds6  CON 1245
En6  CON 1319
Fn6  CON 1397
Fs6  CON 1480
Gn6  CON 1568
Gs6  CON 1661
An6  CON 1760
As6  CON 1865
Bn6  CON 1976
Cn7  CON 2093
```

I did consider using the BASIC Stamp to calculate the Hz values for each note in real time, but it seemed like a lot more work and I was afraid doing so would require additional processing power that we might need later. Subsequently, I just pre-calculated the values for each note.

Next, the original brute force method of determining the appropriate note to play was discarded in favor of a more elegant approach using the PBASIC LOOKUP command to pick a value from a range. The new completed Thereping

## Listing 1

```
AGAIN:
  PULSOUT PING, 5
  PULSIN PING, 1, sample
  ` C blues scale      C - Eb - F - Gb - G - Bb - C
IF SAMPLE1 > 1000 AND SAMPLE1<1047 THEN FREQOUT SPEAKER,100,1047 ` C
IF SAMPLE1 > 1047 AND SAMPLE1<1245 THEN FREQOUT SPEAKER,100,1245 ` Eb
IF SAMPLE1 > 1245 AND SAMPLE1<1396 THEN FREQOUT SPEAKER,100,1396 ` F
IF SAMPLE1 > 1396 AND SAMPLE1<1480 THEN FREQOUT SPEAKER,100,1480 ` Gb
IF SAMPLE1 > 1480 AND SAMPLE1<1568 THEN FREQOUT SPEAKER,100,1568 ` G
IF SAMPLE1 > 1568 AND SAMPLE1<1864 THEN FREQOUT SPEAKER,100,1864 ` A#/Bb
IF SAMPLE1 > 1864 AND SAMPLE1<1976 THEN FREQOUT SPEAKER,100,1976 ` B
IF SAMPLE1 > 1976 AND SAMPLE1<2093 THEN FREQOUT SPEAKER,100,2093 ` C7
GOTO AGAIN
```



program worked like this:

1. Check the distance to the hand above the PING sensor.

```
PULSOUT PING, 5      ` Send a ping out
PULSIN PING, 1, sample ` store response in "sample"
```

2. Determine in which zone the hand was located, and store it in the Note variable.

```
Note = (SAMPLE - LowPos) / Zone
```

3. Use the Note number to LOOKUP the correct note frequency and store that value in the FREQ variable.

```
` C blues scale      C - Eb - F - Gb - G - Bb - C
LOOKUP NOTE, [Cn6, Eb6, Fn6, Gb6, Gn6, Bb6, Cn7], FREQ
```

4. Play the note with the FREQOUT command.

```
FREQOUT Speaker, 100, FREQ
```

After Step 4, just go around in a loop and do it all again. Using this new code, our instrument would efficiently play only notes that would be correct in a specific scale. However, we still had no control of the note's duration or of its timing in relation to other instruments or an external tempo.

## Plays Well With Others

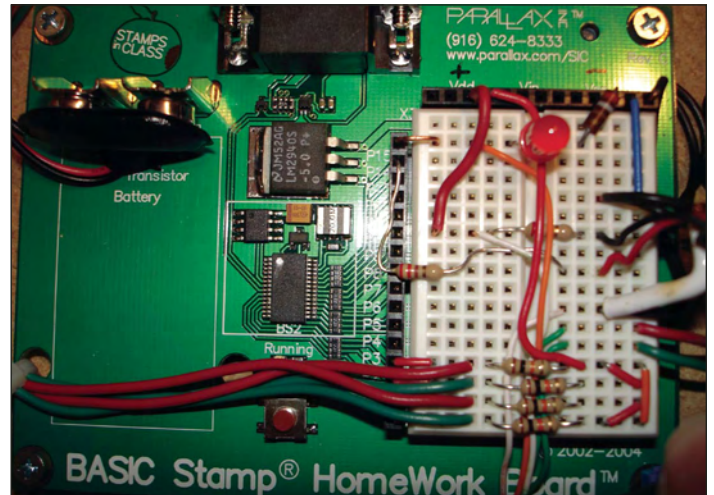
Since the point of the project was to have everyone play *together*, we needed to attack the second thing that could go wrong, namely "playing the note at the wrong time." I figured I could simply program each of the Therepings to look for a "central clock" source before playing a note, to synchronize all the instruments.

Originally, I considered using an LED IR beacon as a sync source. The design consisted of a tall tower (dubbed a "tempo tower") that would allow IR LEDs to be pointed downward to the stage where the instruments would be during a performance. Since our stage was to be a trailer in a parade and a small outdoor pavilion, this solution at first appeared feasible. However, we were slated to play on the pavilion in the daytime when natural UV/IR light would drown any sync signal from the IR LED sync source.

Also, the musicians would need an uninterrupted line-of-sight to the tempo tower if continuous sound was to be maintained. If the players moved about, the Therepings "view" of the tower could be blocked. It started to become clear we needed to re-think our sync.

## Where a Clock? Thereclock!

Though the benefits of a wireless form of sync signal would be large (i.e., no wires to tangle, greater mobility for the musicians, etc.), the downside would be that each instrument would need to contain an on-board power source, speaker system, and associated audio amplifier (or even more complicated, their own radio transmitter!).



■ FIGURE 4. Thereclock Prototype.

Also, in order to be heard in a parade atmosphere, the Therepings would have to be equipped with some pretty beefy amps/speakers that would require some equally hefty batteries. In the end, the additional costs and associated construction time pretty much ruled out going wireless.

Since we had planned to have a central P.A. system, it made sense to simply fall back to a hard-wired approach. I created an experimental master clock system (dubbed the "Thereclock") using one of the Parallax HomeWork boards and some very simple code to toggle pin 15 of the board HIGH then LOW.

```
AGAIN:
HIGH 15
PAUSE 250
LOW 15
PAUSE 250
GOTO AGAIN
```

I added an LED to pin 15 on the Thereclock board, so I could verify the code was indeed toggling the output, and a jumper from pin 15 on the Thereclock Stamp to pin 15 on the Thereping prototype (Figure 4).

Note that they were sharing the same power supply, so they already had a common ground. Once complete, I modified the Thereping code to include a pin definition for SYNC and added this new line just above the existing sound-producing command as shown.

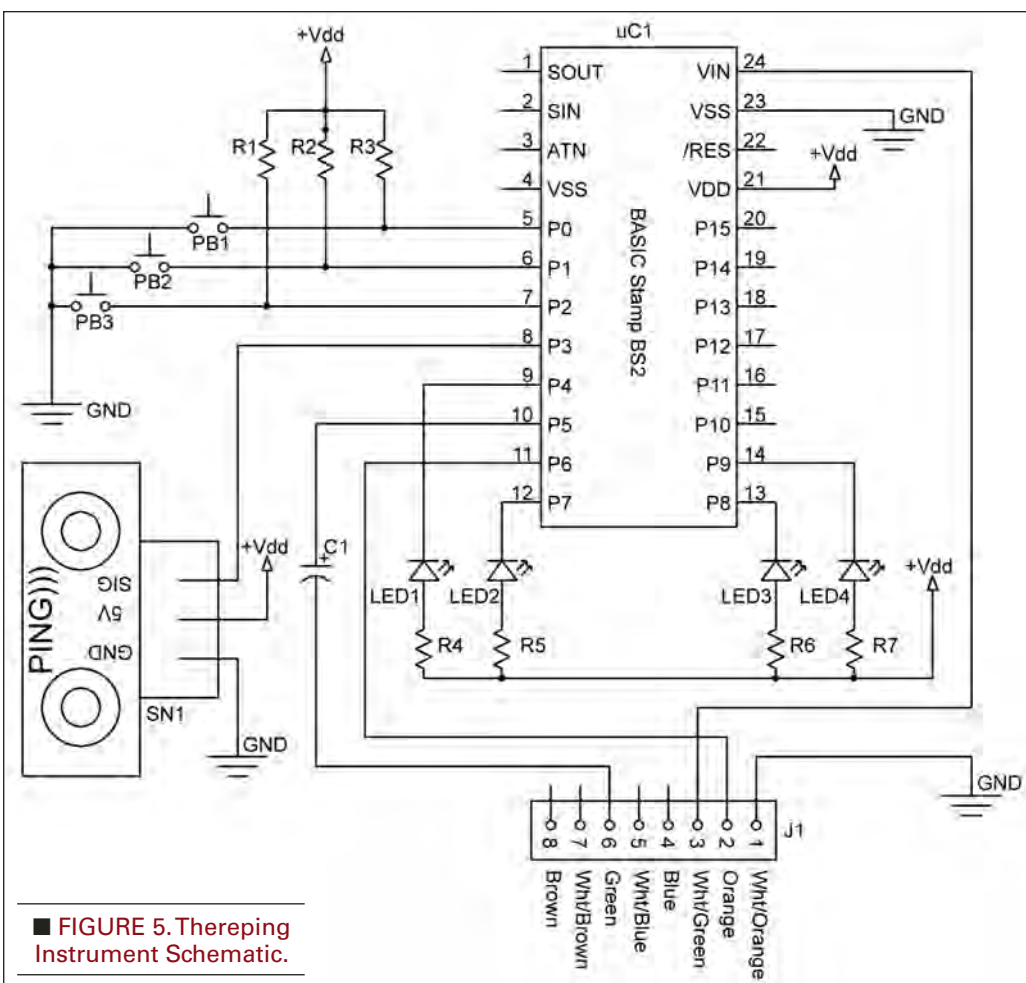
```
SyncWait:
IF SYNC = 0 THEN SyncWait
```

```
FREQOUT Speaker, 100, FREQ
```

I placed my hand over the PING))) sensor, and the notes began to fire off in precise accordance with the blinking of the LED on the Thereclock! Houston, we have SYNC!

## Play it Again ... and Again ... and ...

It was now mid-December, and I had experimented with the prototype Thereclock and Thereping circuits for a





of those pulses is the beginning of the 1/4 note? I decided that since I knew the interval of the clock pulses coming from the Thereclock, I would be able to trigger multiple notes on the Thereping at the onset of a clock pulse before looking to the sync input for a new clock pulse.

For an 1/8th note, I altered the code to play a note two times with a duration that was half the clock frequency before returning to wait for a new clock sync pulse. For the 16th note, it would play four notes at one-quarter the clock frequency (see flow chart in Figure 6).

Though not a perfect solution, it did allow the performer to decide on the duration of the notes and let the Therepings play distinctly different sounding musical themes.

## Droning On and On ...

Now that we could play a fairly intricate solo on the instrument, we were again faced with the problem that many instruments playing similar sounds would tend to blend into just so much noise. Most people expect certain things from music, such as a rhythm section (i.e., bass and drums), an accompaniment of some type (i.e., piano, guitar, etc.), and a discernible lead melody. All I had, so far, was a group of instruments that could play the lead part.

To create a more appealing sound, when the player of the solo part is done, they should be able to drop into the background and accompany or just enjoy what others were playing. Since we were in the same key throughout the song, certain notes could be played to act as a foundation to the music.

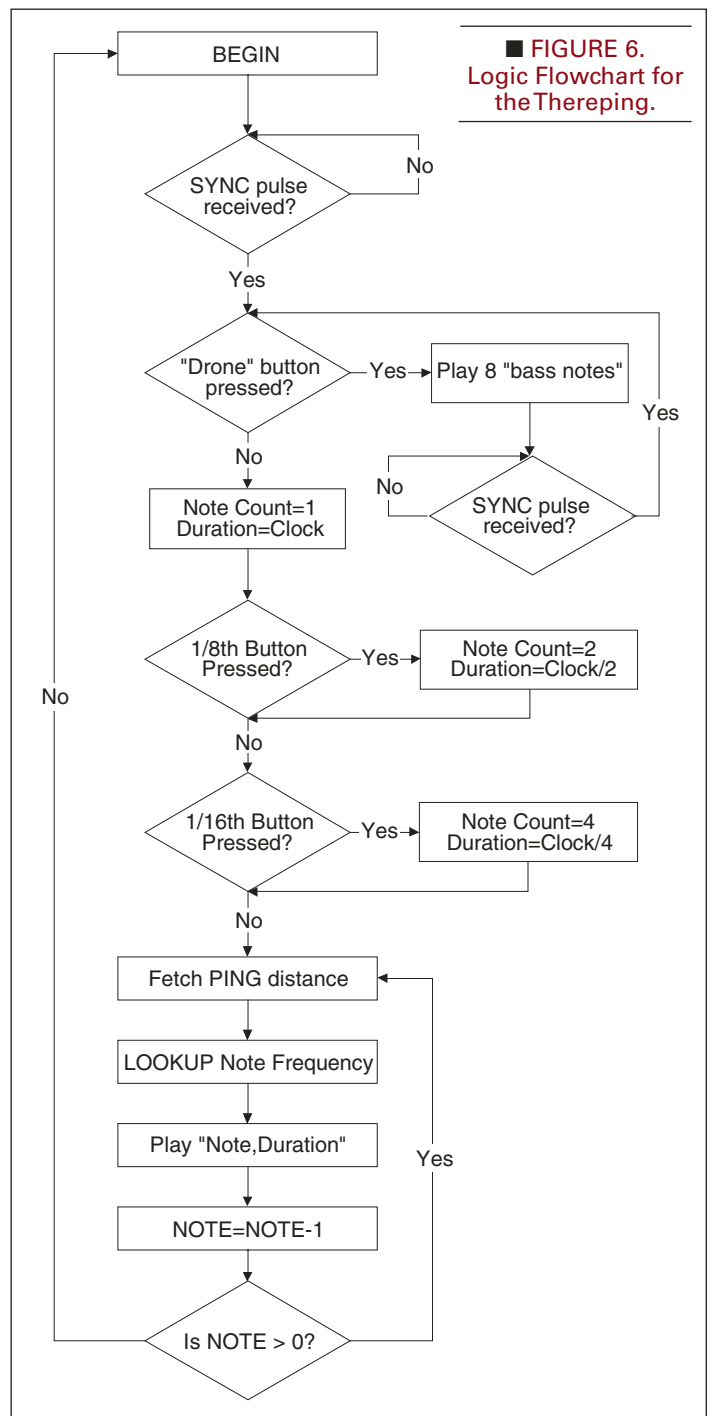
The bagpipe is an interesting instrument in that it has three horns (referred to as drones) that play a consistent chord of notes throughout every song. I thought I could create a sort of drone for the instrument using one of the buttons to tell the microcontroller that it should simply play a preset pattern of notes and ignore the sonar sensor altogether. Then, a player could rest their hand, dance, look around, or listen to others playing.

The instruments would also play something closer to what most people expect to hear in modern music. I added code that would detect the drone button and branch to a routine that simply repeats a series of notes in a bass line. The drone addition to the code is shown in Listing 2.

One thing to notice is that the note frequency values are divided by two in order to drop the frequency by an octave (i.e.,  $Cn4/2$ ). This alters the voice of the instrument to more closely resemble a bass guitar, creating a driving bass line to accompany other players who would be soloing.

I created a couple of variations on the drone part in order to change up the sound and loaded the alternate code into two of the five Therepings. I wanted as much variety in the final song as we could get. You may also notice this is a pretty sloppy way to accomplish this task. From a programming perspective, it would be much tidier to place the FREQOUT commands in a loop.

■ **FIGURE 6.**  
Logic Flowchart for  
the Thereping.



However, we were running out of time and most of the coding was done with an eye towards illustrating the function and allowing quick changes rather than optimizing form. Remember this if you decide to build your own Thereping — there are *lots* of opportunities for improvement!

## Getting Wired

Now we had a proof of concept for syncing multiple



Thereclock and Thereping with Drum Set.

instruments using wire. We just needed a wiring method to easily and robustly link all the instruments to the central clock. I had quite a few Ethernet cables and RJ45 keystone jacks laying about, so I decided to try using regular CAT-5 cable to connect the Thereclock unit to the Thereping instruments. The four pairs in the CAT-5 cable would be plenty for all the needed signals and allow for future expansion if the need arose. See Table 1.

The final schematic for the Thereping shows the CAT-5 connector as the sole I/O point for the instrument providing everything that is needed to operate it.

Since part of our objective was to provide a spectacle, we added some LEDs to each Thereping. This would make interesting visual effects, act as an indicator that the unit was successfully receiving SYNC from the Thereclock, and could be used for diagnostics and development. The final schematic for the Thereping is shown in Figure 5.

## Gimme a BEAT!

Okay, it's now near the end of December. The Thereping has the ability to play lead or solo parts, an accompaniment via a bass line, and we have a way to keep all the instruments in sync. The only thing missing in my mind

Pin	Color	Use	TABLE 1
1	White/Orange	GND	
2	Orange	SYNC	
3	White/Green	V+	
4	Blue	NC	
5	White/Blue	NC	
6	Green	AUDIO	
7	White/Brown	NC	
8	Brown	NC	

board. I plugged the MIDI cable into the MIDI IN of the Yamaha DTXpressII sound module on my drum kit, and then went in search of some example code. It turns out that to make a BASIC Stamp send a simple MIDI command is surprisingly straightforward. The code in Listing 3 plays a constant 1/4 note at about 120 bps using the kick drum sound.

Since the MIDI output of the Thereclock would be sent to the drum machine, it seemed simplest to mount the Thereping directly onto the electronic drum set that held the MIDI module. This would allow me to play the drums to add fills over the straight MIDI beat coming from the Thereclock box. This central location would also make it as easy as possible to connect all the instruments to the Thereclock.

I had a 12" round wooden disk that would make a good base for the BASIC Stamp HomeWork board, as well as the RJ-45 jacks in the wall plate. The circular shape would make it fit in with the cymbals and allow attachment to a cymbal holder by simply drilling a single hole in the edge of the board. I built the prototype and tested it with the Therepings. It was successful in syncing up all the Thereping units!

However, it would be necessary to find a way to STOP and START the unit to designate the beginning and ending of songs. I took some PC case back planes and bent them to fit on the side of the unit facing the drummer, and then installed and labeled four pushbuttons to use for controls. Now I had the ability to START and STOP the song, and I also added the traditional whistle eight beat intro and outro that would normally be used by a drum major to start and stop a marching band.

Since the button's use is determined by software, this would also allow me to re-purpose the functions in the future (i.e., song select, tempo adjustment, etc.). I also removed the 1/4" right and left audio jacks and replaced them with a single 1/8" female jack so the

### Listing 3

```
MidiOut PIN 15          \ MIDI Output
MidiBaud CON $8000 + 12  \ 31.25 kBaud - open
Channel CON 8           \ MIDI Channel
NN CON $90 | Channel    \ note on
NX CON $80 | Channel    \ note off
```

AGAIN:

```
SEROUT MidiOut, MidiBaud, [NN,$24,$7f] 'NoteOn kick note# 36 at full velocity
PAUSE 300
SEROUT MidiOut, MidiBaud, [NX,$24,$7f] 'NoteOff kick note# 36 at full velocity
PAUSE 300
GOTO AGAIN
```

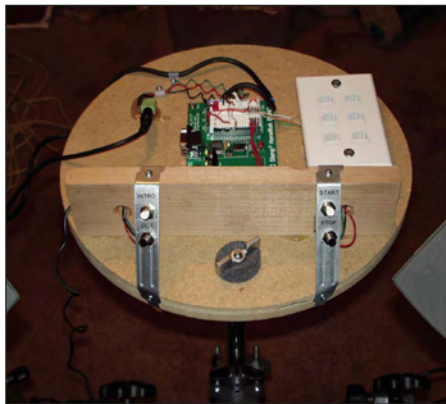


audio could be sent directly to either a small computer speaker type amplifier or, using a 1/8" to RCA adapter, sent to the line input of a mixing console.

On the mixer, I panned the first three Therepings inputs to the left and the second

set to the right, then added some echo and a touch of reverb. I didn't implement the audio out LPF circuit shown in the BASIC Stamp manual because the consensus from people who had heard the prototype is that the buzzy sound was more appealing than the duller sound that came out after the LPF was applied.

The finished schematic for the Thereclock is shown in Figure 7. I invited the The Robot Group members over for a rehearsal (Figure 8) and then we were ready for the debut performance before an expected crowd of well over 60,000 people! Yikes!



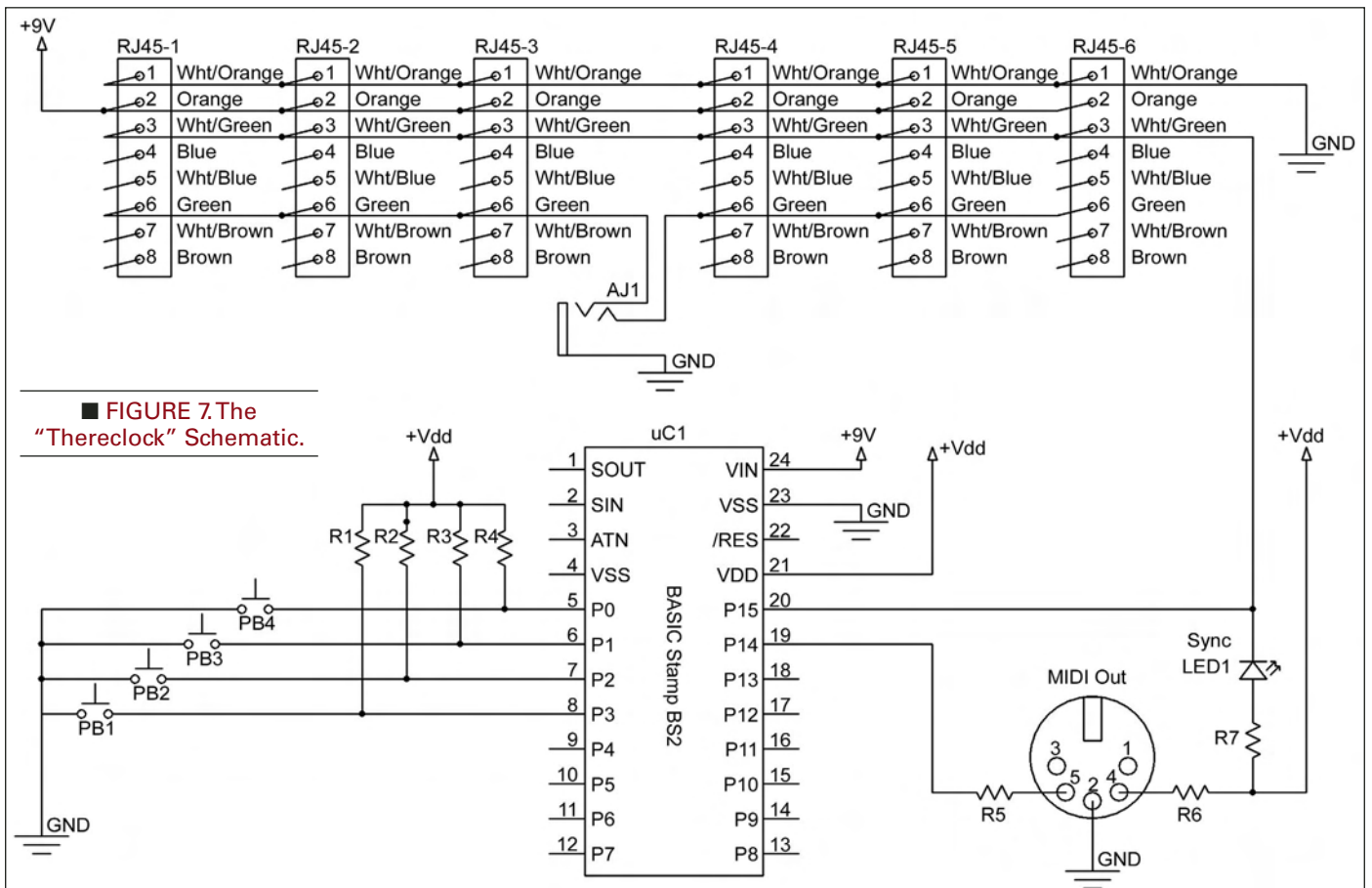
**Thereclock Finished and Mounted.**



**FIGURE 8. The Thereping Rehearsal.**

## The Debut

On the morning of December 31, 2005, we loaded all the equipment onto a 20-foot trailer and hauled it to the pavilion where we set up the P.A. system and the rest of the Thereping equipment. We immediately drew a crowd by playing for a short while (Figure 9), before offering the Thereping units to people in the crowd so they could exper-



**FIGURE 7. The "Thereclock" Schematic.**



■ **FIGURE 9.** Nic Graner playing a Theraping on the Pavilion.



■ **FIGURE 10.** Theraping Band sporting their hats while waiting to play in the parade!

iment with the music. We had a crowd of people that watched the jam session for a good, solid three hours!

There were TV cameras from both local and national news organizations present. The most exciting part was

the people participating. After just a few moments of instruction on what the parts of the instrument were, folks were able to pick it up and start playing music together instantly! This part of the show was a major success, but we still had to tear down the entire system and reassemble it on the trailer for the parade.

## Showtime!

Once everything was hooked back up (and amazingly all the systems survived the relocation), we carefully drove the trailer to the start of the parade route. We powered the entire show using a 2.5 kW gasoline generator on the bed of the pickup truck and put the 400 watt stereo P.A. system on the trailer with the musicians. Each of us wore a fanciful digital hat crafted by Denise Scioi and others of The Robot Group (Figure 10).

We played music for over an hour and had people clapping and dancing alongside the trailer as we went down Congress Ave. in Austin, TX. First

## ACKNOWLEDGMENTS

■ I would like to thank the following people who were critical in making the Theraping a reality:

*Rick Abbott, Paul Atkinson, Derek Bridges, Don Colbath, Bob Comer, Kym Graner, Nic Graner, Walt Graner, PY Hung, Eric Lundquist, Tom Morin, Gray Mack, Denise Scioi, Mike Scioi, and Sharon Sudduth.*

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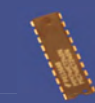
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## RESOURCES

■ Vern Graner's "Theraping" website  
[www.theraping.com](http://www.theraping.com)

■ The Robot Group  
[www.robotgroup.net](http://www.robotgroup.net)

■ First Night Austin  
[www.FirstNightAustin.org](http://www.FirstNightAustin.org)

■ Parallax, Inc.  
[www.Parallax.com](http://www.Parallax.com)

■ Yamaha DTXpress User Group  
[www.DTXpressions.com](http://www.DTXpressions.com)



Night Austin officials estimated that over 100,000 people viewed the parade that night. It was an amazing experience! I think we fulfilled our mission to create a fun and interesting spectacle.

## The Future

Though I consider this project a success as it stands, I also feel there is plenty of room for improvement for the equipment. For example, we've barely scratched the surface of the capabilities of the Thereclock to produce MIDI. With a bit more programming, it should be possible to create a number of different types of beats or even songs for playback.

The extra lines in the Ethernet cable could be used for sending song selection information to the Therepings or for allowing the Thereping to send a stereo signal to the Thereclock, thereby enabling the player to select which channel

their signal is sent to (i.e., clean/distorted/echo or not, etc.).

The patterns that can be chosen on the Therepings could also be expanded to include swing beats or triplets, for example. The drone setting could be altered to include MIDI output sent back via the CAT-5 cable or to produce chords or blues-style walking bass lines. In short, this instrument has barely been touched

in capability! If you do decide to build one, I would love to hear how your project proceeds. All the source code, schematics, and associated material for helping build your own Thereping and Thereclock, along with audio and video clips, are available at [www.nutsvolts.com](http://www.nutsvolts.com) or at my website listed in the Resources sidebar. If you have any questions, feel free to contact me at [vern@thereping.com](mailto:vern@thereping.com) **NV**

## THEREPING INSTRUMENT PARTS LIST

- ☐ LED1 — Red LED
- ☐ LED2 — Amber LED
- ☐ LED3 — Blue LED
- ☐ LED4 — Green LED
- ☐ J1 — RJ45 Keystone Jack
- ☐ C1 — 10µF Capacitor
- ☐ SN1 — Sonar Sensor
- ☐ PB1-3 — N.O. Momentary
- ☐ R1-R3 — 100 Kohm
- ☐ R4-R7 — 330 ohm
- ☐ uC1 — BS2 HomeWork Board

## THERECLOCK PARTS LIST

- ☐ LED1 — Red LED
- ☐ J1-6 — RJ45 Keystone Jacks
- ☐ AJ1 — 1/8" Stereo Audio Jack
- ☐ MJ1 — 5 pin DIN MIDI Jack
- ☐ PB1-4 — N.O. Momentary
- ☐ R1-R4 — 100 Kohm
- ☐ R5-R7 — 330 ohm
- ☐ uC1 — BS2 HomeWork Board

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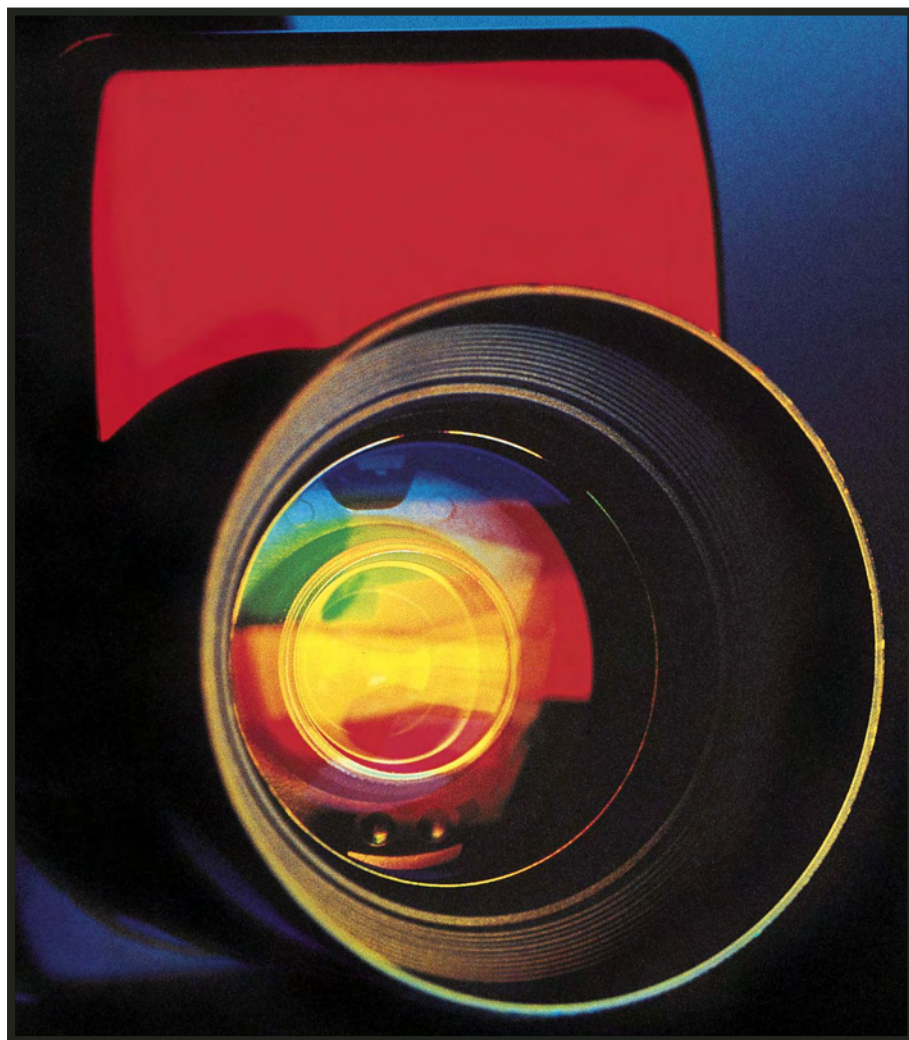
# VIDEO



by:  
Brian  
Mork

## *Digitizer Choices*

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**T**his short article won't accomplish the Herculean feat of bringing you up to speed on everything, but it is an attempt to cut through the marketing trivia, summarize user feedback from the web, and simply let you know what to buy. I'll also include recommendations for upgrades to your computer to handle video editing. As you read, be sure to refer often to the sidebar on video formats.

### Introduction

There are basically two broad groups of video formats you'll come across: those meant for display on a PC computer and those meant for distribution on optical disks. Some of the formats meant for PCs are MPEGs, AVI, AVI-VF, Quicktime, WMF, Real Video, and DivX. Because my goal was to convert VHS tapes onto optical disks, the emphasis of this article is formats that are associated with optical disks such as CDs and DVDs that play in portable or stand-alone home entertainment type players.

### Purchase Issues

Digitizing video, editing video, and burning onto optical media in a PC environment requires attention to hardware and software issues that are often

**You can spend between \$22 and several hundred dollars buying video digitizers suitable for use with your home computer. In other words, there are enough confusing standards and qualities to keep anybody employed full time figuring it all out. What's the difference? What's good enough? A friend likened the video capture industry to the mythological hydra in the swamps of Lerna, slain by Hercules: when you chop off one head, two more grow in its place.**



intertwined. Deciding on a few primary issues will winnow the field of products down to a manageable number.

First, choose if you're going to work on a laptop or desktop. This directly influences your decision to purchase a digitizing board with a USB connection or a plug-in computer card. Because a 30 GB laptop hard drive probably isn't going to be enough storage space, I chose to do video work on a desktop.

You might want to consider a digitizing card that also has a TV tuner. They do the same recording operations as a video-only card, plus you can change channels under computer control. There are good programs to do this under Linux and Windows.

With a video-only unit, you could use your VCR/tuner to change channels and then feed the video into your PC, but with an integral unit, you may gain the ability to mimic all the behavior of a TiVo unit. I have bad TV reception where I'm at, and I don't have cable, so I didn't do this option.

I had a chance to experiment with the hardware and software from two different models:

- K-World "V-Stream Xpert DVD Maker" VS-L883D. Software includes Cyberlink's Power Producer 2 Gold and PVR-Plus. Out-of-pocket cost is about \$45 from on-line auctions, \$31 (or \$22 for bare-bones refurbished) mail order from Newegg's website.

- ADS "DVD Express" USBV701. Software includes CapWiz 3.1, Ulead Video Studio 7SE, Ulead Movie Factory 2SE, and MuveeAuto Producer. Street price is about \$90+s/h from mail-order websites, or about \$83 from an on-line auction. Step up to the USBV702 "Instant DVD 2.0" if you want to play from your PC out to a video recorder or TV (~\$100 from web auctions). Step up to the USBV703 "Instant DVD+DV" if you want to connect directly to a digital video camcorder.

Choosing how much functionality is in the hardware vs. software is also a dominant issue when shopping for video equipment. For instance, Plextor's PX-M402U USB unit has a real-time MPEG-4 hardware encoder.

Others, such as the PVR-Plus software, use plug-in modules to do this. Others, such as the ADS models mentioned above, don't do MPEG-4 at all. Generally, doing more in software gives you flexibility and upgradeability, but needs more computer power.

Even with a hardware encoder, you can't get totally away from software encoding because, oftentimes, you have to re-encode video after you've edited it. That's always in software, no matter what hardware you record with. Software encoding, or "rendering" can take a lot of time. On my 1.2 GHz Athlon AXP, saving DivX MPEG-4 to 6 Mbps MPEG-2 runs slower than real time. Rendering from MPEG-2 back to MPEG-2 (6.8 Mbps max rate) ran about 10X faster than real time.

Lastly, before you make a purchase

decision, download a copy of the free program AVIcodec and study its output. The two main screens of information are shown in Photos 1 and 2. Photo 1 shows you what codecs you already have on your computer. In my case, there are 13 different codecs. The screen in Photo 2 will scan any file or directory of files and tell you what video formats they are.

In the sample printout, I had 14 files, all MPEG-2 of varying screen sizes, bit rates, and aspect ratios. If you use this program on your computer, it will give you knowledge to help you choose what to buy and how to make your own videos.

## Installation

Installation of a USB digitizer will dangle more cables over the back of

PHOTO 1. AVIcodec identified 13 different codecs on my computer.

ID	name	version	vendor	filename
cvid	Cinepak® Codec	1.10.0.6	Radius Inc.	C:\WINNT\system32\iccvid.dll
divx	DivX® Codec for Windows	5.2.1.1338	DivXNetworks, Inc.	C:\WINNT\system32\DivX.dll
iv31	Intel Indeo R3.1	1.10.0.6	No company info	C:\WINNT\system32\iv32_32.dll
iv32	Intel Indeo R3.2	1.10.0.6	No company info	C:\WINNT\system32\iv32_32.dll
iv50	Intel Indeo® video 5.10	R.5.10.15...	Intel Corporation	C:\WINNT\system32\iv50_32.dll
m261	Microsoft H.261 ICM Driver	4.4.3385	Microsoft Corporation	C:\WINNT\system32\msh261.drv
m263	Microsoft H.263 ICM Driver	4.4.3385	Microsoft Corporation	C:\WINNT\system32\msh263.drv
i420	Microsoft H.263 ICM Driver	4.4.3385	Microsoft Corporation	C:\WINNT\system32\msh263.drv
mrlc	Microsoft RLE Compressor	5.00.2195...	Microsoft Corporation	C:\WINNT\system32\mrlc32.dll
uyvy	Microsoft UYVY Video Decompressor	5.3.00000...	Microsoft Corporation	C:\WINNT\system32\msyuv.dll
yuy2	Microsoft UYVY Video Decompressor	5.3.00000...	Microsoft Corporation	C:\WINNT\system32\msyuv.dll
yuyv	Microsoft UYVY Video Decompressor	5.3.00000...	Microsoft Corporation	C:\WINNT\system32\msyuv.dll
msvc	Microsoft Video 1 Compressor	5.00.2134.1	Microsoft Corporation	C:\WINNT\system32\msvidc32.dll

Filename	V. codec name	A.1 codec name	V. resol.	V. bitrate	V. aspect ratio
D:\ppwork\EOSS21_PVR_DVD.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	720 * 480	3950 K...	4:3
D:\ppwork\EOSS33_PVR_DVD.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	720 * 480	3950 K...	4:3
D:\ppwork\EOSS-NewsReport_PVR_DVD.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	720 * 480	3950 K...	4:3
D:\ppwork\EOSSxx_PVR_DVD.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	720 * 480	3950 K...	4:3
D:\ppwork\GlacierFS_PVR_DVD.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	720 * 480	3950 K...	4:3
D:\ppwork\FalconGoldStory_PVR_SVCD.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	480 * 480	2300 K...	4:3
D:\ppwork\Glacier_SVCD.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	480 * 480	2400 K...	16:9
D:\ppwork\1227_224816.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	352 * 480	6800 K...	16:9
D:\ppwork\1227_233719.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	352 * 480	6800 K...	16:9
D:\ppwork\EOSS33_PP2_DVD_SP.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	352 * 480	6800 K...	16:9
D:\ppwork\EOSS33_PP2_DVD_SP.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	352 * 480	6800 K...	16:9
D:\ppwork\EOSS-NewsReport_PP2_DVD_SP...	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	352 * 480	6800 K...	16:9
D:\ppwork\EOSSxx_PP2_DVD_SP.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	352 * 480	6800 K...	16:9
D:\ppwork\FGNewsReport_DVD_SP.mpg	MPEG 2 (SVCD/DVD)	Mpeg-1 audio Layer 2 [0x0c]	352 * 480	6800 K...	16:9

File : 102 MB (100 MB), duration: 0:03:22, type: MPG, 1 audio stream(s), quality: 98 %  
 Video : 95 MB, 3950 Kbps, 29.970 fps, 720\*480 (4:3), MPG2 = MPEG 2 (SVCD/DVD), Supported  
 Audio : 5.40 MB, 224 Kbps, 48000 Hz, 2 channels, 0x51 = Mpeg-1 audio Layer 2 [0x0c], Supported

PHOTO 2. The AVIcodec program shows 14 files — all MPEG-2 of varying screen sizes, bit rates, and aspect ratios.

your computer and requires another power strip plug-in. For a PCI card unit, you'll have to open up the box and install the card, which will put some load onto your existing power supply. In exchange, you'll be limited only by the CPU and bus speed rather

than I/O bandwidth. For both the USB and PCI units I used, installing hardware was painless and straightforward.

## Software

With most video software, you'll

find a main display screen to edit clips, and some sort of a time line below to sequence clips and transitions. A dominant theme you'll experience over and over is that video editing software is centered around combining small clips of video into a movie. One of my goals was to edit sequences up to several hours and clip out unwanted pieces (such as moving VHS tapes to DVD). This conflicted with the dominant theme of building videos from clips because clipping off just two seconds of lead-in garbage required rendering of the entire remaining hour and 58 minutes!

For all the software, I would implore manufacturers to write real documentation. It gets really frustrating to read, for example, that the "enable high-quality preview" button enables a high quality preview. Oh really?! This is not documentation, nor a user manual. I need to know what high quality means and what the choice impacts — why the choice is good or bad for certain circumstances, etc.

## ADV Software

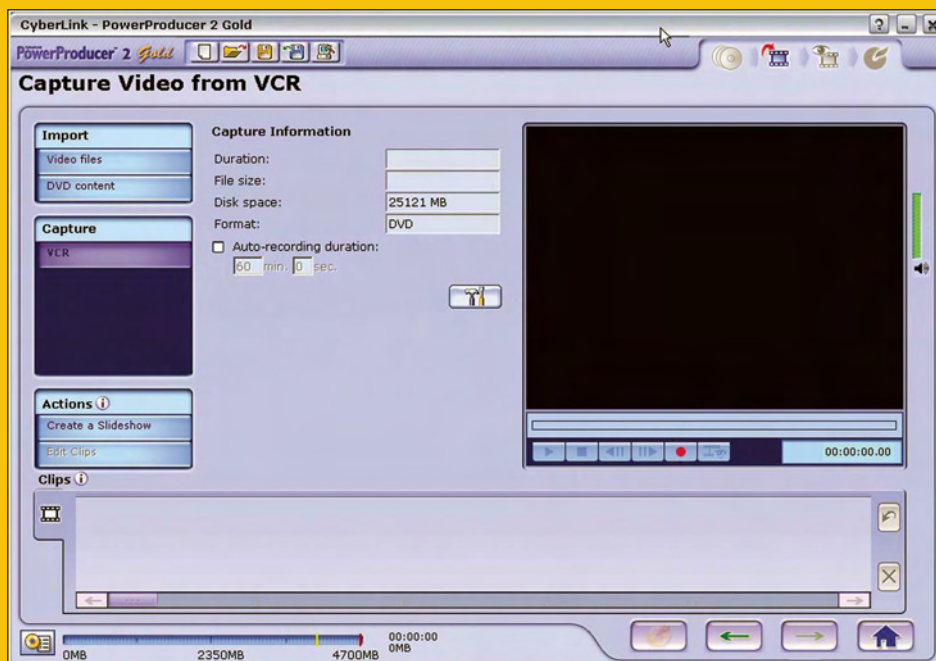
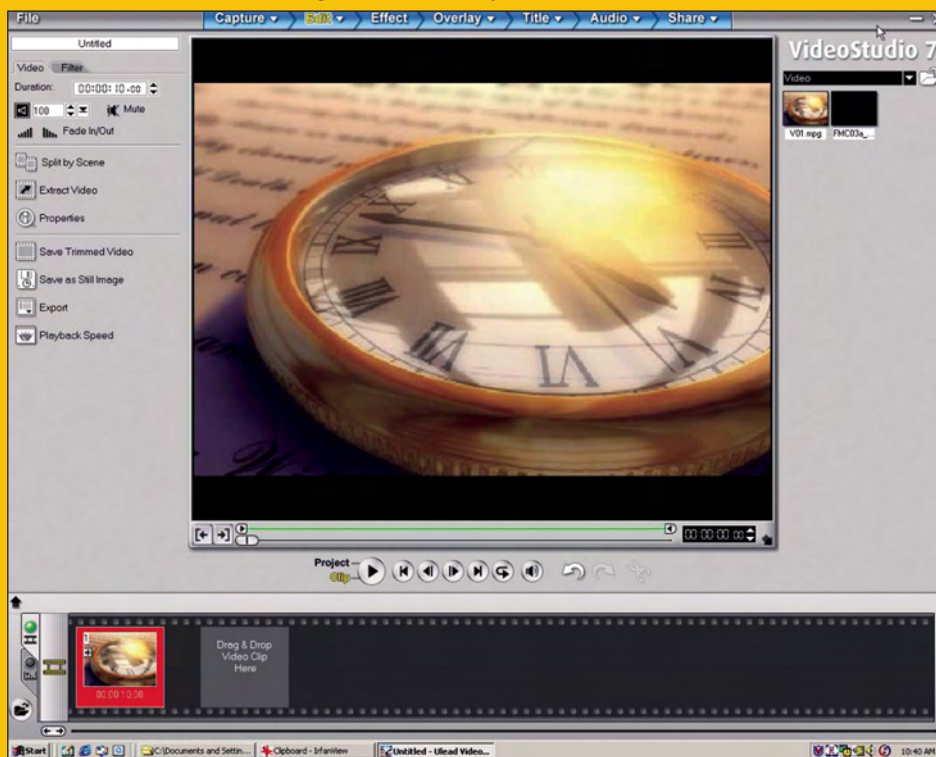
ADV software used up more than an hour of time getting it to install happily on my computer. A turning point in my efforts to get CapWiz working was when I realized the install program generated ~/DVD-DV directories, and the software was looking for directories named ~/DVD. After manually fixing that, the software suite started operating fine.

The Video Studio console seemed slightly confusing. For example, what's the difference between clipping on the main display screen, or clipping on the "extract video" menu screen, or clipping on the main time line display? Similarly, Share, Export, and Save Clip options appear to have overlapping functions and unexplained sub-options.

Movie media formats, such as DVD, allow chapters and scenes to be specified so you can jump right to what you want. This software provides an option to automatically detect and create scene boundaries, similar to the Pinnacle Studio SE 8.8 software.

It is hard to get the threshold set right to be useful (either it senses no

**PHOTO 3.** Menu choices are on the left. To the right are all the clips you've browsed to or created. On the bottom is the sequence of clips that will become a single movie when you burn the disk.



**PHOTO 4.** Power Producer offered easy-to-understand options.



scene changes or senses way too many scene changes). Mostly, you have to know the sequence of scenes and manually specify boundaries.

Lastly, Video Studio reliably provides scene clipping, accurate to one frame.

Using Movie Factory, separate clips you load up automatically become DVD default menu choices. You can edit, delete, or add to the default menu. Burning clips to CD or DVD was no harder than burning an audio or data CD-ROM.

I was disappointed that for short video material, I could not burn DVD quality onto a CD. Movie Factory allows this, but unfortunately, it wouldn't play on my stand-alone DVD player. Even if your clips are short, you have to record on the DVD media to keep the DVD quality. Of course, you can just copy DVD-quality .mpg files onto a CD, but then the disk is made to be read by a PC, not a DVD player. If you save on a CD-ROM as Video CD or Super Video CD format, video quality degrades to that format's quality.

## K-World Software

The K-World digitizer hardware came with two programs. Cyberlink's Power Producer 2 Gold (PP2) is "granny's" version of acquisition, edit, and burn software. It looks pretty, acts predictably, and offers minimum confusing choices. It records DVD-class video using three pre-canned combinations of video parameters (HQ, SP, LP). It will also save in VCD- and SVCD formats, both of which have stabilized on a single set of parameters, so there are no quality choices. Additionally, instead of recording video, you can load existing video files, or rip from an unprotected DVD.

The down side is that such clarity limits capability. One Internet reviewer said the K-World software won't save .mpg files and this is what he was referring to. Notably, once the video is trimmed, you can't save it back to an .mpg file. You can save a project file that remembers the source videos and clips you've done, but the only destination for your work is to burn it on optical media. Overall, you're expected to

repeatedly do the same simple process: record, mark clips, burn. No extra stuff.

PP2 does do variable encoding bit rates, similar to the Plexor or Ulead software. This saves disk space when successive frames of video are similar to each other.

Audio volume is controlled by the Windows control panel, and I never could get enough volume for some tapes that had a weak sound track. It would be nice if video editors offered a "normalize to -3 dB" function for the sound track, similar to how the sound-editing program Audacity does.

The other K-Word package (PVR-Plus) is a GUI control console for a number of separate programs, very reminiscent of the Linux way of doing things. It allows you to capture video, convert video formats, edit video, export disk copies, and burn optical disks.

The capture software requires

administrator privileges to properly run. It is very versatile in terms of parameters you can set, which include bit rates, aspect ratios, color encoding, sound parameters, etc. The variety of settings helps mitigate the fact that it cannot record with variable bit rates. It does allow scheduling to record video at pre-determined times.

It can save video as MPEG-1, MPEG-2, DV-AVI, or AVI. If you separately download an MPEG-4 encode (Microsoft's or DivX), it allows recording to MPEG-4.

The editor GUI design is weak. It made me think of old DOS GUIs built with special extended ASCII characters, and I'm still grappling with the concept of merging filters, transition effects, and sound tracks when they're shown as alpha names in a time sequence, without the video clip they apply to. It does let you export MPEG-4 .avi files

## ANCILLARY COMPUTER UPGRADES

**Working with video may convince you to do other upgrades or modifications to your computer. Some I'm aware of are:**

- Upgrade your video player software. Video generates big files (up to 4,700 MB destined for a DVD). Can your media player play them? My DivX player could not play these large files. Microsoft's Media Player seems to work fine, but could not readjust the aspect ratio to make some recordings look right (with SVCD 480 x 480 formats destined for a TV, video is squished together sideways when displayed on a computer pixelated screen). Real Player could not read SVCD video files at all.

- Buy a big hard drive. I recently picked up a 160 GB for \$37 after rebates. Less than 20 GB of free space will give you grief. You'll fill up 80 GB quickly. You must get rid of any FAT16 partitions, which are limited to 2.1 GB.

- I prefer to have a FAT32 disk partition on my computer, so files are read/write accessible by both Windows and Linux. Without heroics, FAT32 partitions are limited to 32 GB. You may fill this doing video editing, so plan for alternatives such as multiple partitions if you dual-boot.

- Video files can easily go over 2 GB, and there are problems with files this large (do a Google search on "2 GB limit"). For

me, using Mandrake 9.2 Linux, I can copy them from Windows FAT32 to Linux ext3, but I get errors when I try to copy the file from my ext3 partition back to a FAT32 partition. Consider chopping your videos into smaller pieces (many programs have an option to do this automatically). Combining clips back into single movies is trivial.

- Buy RAM, especially if you'll do a lot of software encoding. The Windows 2000 Task Manager showed that rendering took 86% of my CPU and nearly 100% of my 256 MB memory, so I expanded from 256 to 768 for \$60 via an on-line auction.

- My 15" LCD screen is more than enough. Most video clips are at smaller resolution and don't press the limits of typical computer console screens.

- Upgrade your home network. Passing GB video files back and forth between computers is the first time my 10 Mbps Ethernet link appeared slow.

- If you buy a USB encoder, upgrade to USB 2.0. Most video capturing manufacturers specify USB 2.0 to get its 40X faster I/O speed. I had no trouble running nominal digitization rates for a few days at USB 1.0, but I didn't test all the upper limits. After communication overheads, the 12 Mbps limit of USB 1.0 is very close to the video rates you'll want to acquire.



**PHOTO 5.** The smaller control window can bring up any of four separate programs. Video editing is shown here as the second program.

with even more options than the capture software. I particularly liked the DivX plug-in's option to specify a file size, and let it choose the bit rate to

match. At times, the PVR-Plus editor added a few extra frames to the beginning or end of a cut, which was frustrating after waiting many minutes

for an edit to re-render back to disk.

The MPEG converter allows you to read in AVI, DV-AVI, MPEG-1/2, ASF, WMF, DivX, and DAT files. The converter can output in seven MPEG-2 formats and seven MPEG-1 formats, each with customizable parameters, including variable bit rates.

The PVR-Plus CD and DVD burning program is functional, but weak on features. For instance, it does no auto-conversion, expecting only one type of file for each of the formats: DVD, SVCD, or VCD. You must record everything in the right format, or use the convert program first. It can generate menus for DVDs, but not for VCD or SVCD.

## Forced to Choose — Resolution or Bit Rate

Power Producer 2 has only three DVD qualities (HQ, SP, LP), and specific parameters are fixed. Resolution of the SP setting is 352 x 240, and I initially

## VIDEO FORMATS

Table 1 shows a number of video data stream formats. This list is not comprehensive, but rather reflects what I found from multiple manufacturers as I shopped for video capture hardware. Notice there are several standard resolutions, encoding schemes, and bit rates that keep showing up, but also notice that some names mean different things when used in context of different companies' products.

I included a number of Plexor formats in the table even though I didn't use their hardware because they offer free sample video clips for comparison, available at [www.plexor.com/english/products/ConvertX2advancedtechspec.htm](http://www.plexor.com/english/products/ConvertX2advancedtechspec.htm)

### Language Glossary

Identifying exactly which format you're talking about sometimes gets blurry. If you refer to a "DVD format," 99% of the time you're implying MPEG-2 encoding. (There is room in the official specification for MPEG-1.) The reverse isn't true: only some combinations of MPEG-2 play successfully on DVD players. You can go up to about 9 Mbps and still be "legal" for DVD players, but if you average much above 5 Mbps, a standard length movie won't fit on a single DVD disk. Some MPEG-2 resolutions are optimized for computer display, such as the 640 x 480 resolution listed in the table. If you'd like

a technical overload of what each term means, there's a comprehensive glossary at [www.afterdawn.com/glossary](http://www.afterdawn.com/glossary)

### TV Presentation vs. Computer Screens

Standardized resolutions for movie viewing are SIF (352 x 240), F-D1 (720 x 480), and 1/2-D1 (352 x 480). For comparison, all NTSC televisions are (... x 525), with horizontal resolution specified at several hundred up to a thousand dots per line. The horizontal resolution isn't an exact number, but rather more of an analog bandwidth of how fast the electron gun can be modulated.

Unlike computer screens, the pixel resolution of a video format doesn't imply the aspect ratio. You can think of it this way: Video formats often use non-square pixels. What's really going on is that analog TV video for each line isn't naturally pixels — it's just a changing voltage that can be digitized at fast rates to get many horizontal pixels, or slower rates to get less horizontal pixels. On the other hand, the number of lines in each TV frame is unambiguous. A digitized video file can declare internally what aspect ratio is to be displayed, or your video player makes the choice. Common ones are 4:3 for TV, and 16:9 for DVDs. I found a decent technical tutorial at <http://members.aol.com/ajaynejr/vidres.htm>

Audio tracks are pretty standardized on MPG-1 Level 2 encoding at 44.1 kHz or 48 kHz sample rate, although older stand-alone DVD players may require LPCM compression. Valid audio bit rates for non-PC play maxes out at 448 kbps on the DVD format, but most optical disk video uses less.

### Disk Sizes

Lastly, standard disk sizes set some of the norms. For example, fitting 120 minutes on a 4,700 MB DVD requires 39 MB/min or less, so most commercial DVD MPEG-2 recordings use this range. SVCD and VCD formats mimic DVD behavior (menus, chapter), although the "legal" combination of video parameters gives you slightly lower quality for these formats. Run times are about 30-40 minutes for SVCDs and 60 minutes for VCD.

Stand-alone DVD players are typically able to play any of the three formats, but you can't mix them. In other words, storing high quality DVD on a CD won't let you store much, but there are times when I wish I could do this for short clips. DVD quality on a CD will play in my computer, but not on my stand-alone DVD player. If you'd like to adventure off and try non-standard combinations of video and/or audio, [www.afterdawn.com/guides](http://www.afterdawn.com/guides) will help get you started.



wanted to switch to higher screen resolution. But using the HQ setting generates enough bits so that only 86 minutes can be stored on a 4,700 MB DV platter. I wanted something in between!

PVR-Plus does let me choose custom bit rates, but it doesn't do the more efficient variable bit rate within a recording. With a fixed rate, 5 Mbps is the maximum to fit 120 minutes on a 4,700 MB DV platter. I could do this and then run it through the PVR-Plus converter, which does allow variable bit rates.

In contrast, ADV's CapWiz let me directly adjust rates and use variable recording. I often used a "Hollywood standard" of 720 x 480 (F-D1) at 4.5 Mbps maximum rate with CapWiz software. With the PP2 program, I've settled on 352 x 480 at 6.8 MBPS maximum bit rate. I can't tell the difference when played back on a TV screen.

## GOAL — Fit the Movie on a Disk

The primary issue affecting whether a video sequence will fit onto a disk is the bit rate. Predictably, this is also the most powerful indicator of video quality. Other issues are great for marketing folks to toss around

when trying to sell a product, but the confusion doesn't help someone understand the necessary trade-offs.

For example, as mentioned above, 720x480 at 4.5 Mbps looks the same to me as 352 x 480 at 6.8 Mbps. One has more screen resolution, but the other digitizes with less compression. The two phenomena balance out with about the same overall file size per minute of video. Comparing MPEG-2 and MPEG-4, it seems to be a preference of what type of artifacts you like: overall fuzziness or periodic streaking.

I had a goal of putting 120 minutes of video onto a DVD. The PP2 DVD SP mode generates reasonable quality playback using a maximum of 6.8 Mbps. Video has few artifacts (aggregate pixel squares, blocks of colors, indistinct striated object edges, ripples around objects), but the screen resolution is only 352 x 480, and this creates slight overall fuzziness — indiscernible on a typical TV, but visible on a PC monitor if you know what to look for. Choosing the PP2 DVD HQ recording mode gives 720 x 480 screen resolution and to keep the same quality with finer resolution, the bit rate goes up to 8 Mbps maximum. The tradeoff? Much larger files, limiting play time to about 85 minutes.

In order to escape this trap of the

bit rate, I tried moving to MPEG-4 encoding instead of the DVD MPEG-2 standard. There are two competing encoding schemes widely used in the MPEG-4 family: Microsoft's two versions and the DivX encoder. Both are freely available on the web.

The DivX encoder, operating at 15 MB/min, generally had the same visual appeal as the MPEG-2 encoder running at about 38 MB/min (the 120 minutes per DVD max rate due to size limits). Although switching encoder types let me get similar quality at lower bit rates, I still use mostly MPEG-2 because it's readable by more DVD players, and it doesn't matter to me if I fit 120 minutes onto a 4,700 MB DVD in MPEG-2 with no space left over, or if I fit 120 minutes of MPEG-4 with space left over.

To press DivX's limits, I did two encodings while keeping the file sizes down to 15 MB/min. Sure enough, when I switched from 352 x 240 resolution to 720 x 480 resolution, horizontal striations showed up near the edges of moving objects on the video. As with the MPEG-2 encoder tests, higher screen resolution sacrificed compression quality, and "better" was a subjective preference.

The target for DivX and Microsoft's MPEG-4 recordings seems

352 x 240, a.k.a. SIF  
720 x 480, a.k.a. F-D1  
352 x 480, a.k.a. 1/2-D1

TABLE 1

Company/Product	Name	Format	Resolution	Bit rate, avg → max (Mbps)	File Size (MB/min)	Minutes/disk	Comments
Plextor M402U	DVD HQ	MPEG-2	F-D1	6.0 → 9.8	46.7		
CyberLink PP2	DVD HQ	MPEG-2	F-D1	3.4 → 8.3	57.5	60	
Plextor M402U	DVD GQ	MPEG-2	F-D1	4.5 → 9.8			
Plextor M402U	DVD SP	MPEG-2	1/2-D1	3.0 → 9.8	15-77.0	60-130	
CyberLink PP2	DVD SP	MPEG-2	1/2-D1	3.4 → 6.8	27.0	120	Striations, not blocking
PVR-Plus	DVD	MPEG-2	F-D1	4.0	30.0		Blocking, not striations
PVR-Plus	MPEG-2	MPEG-2	640 x 480	4.0			
CyberLink PP2	DVD LP	MPEG-2	SIF	1.8 → 3.5	15.2	180	
Plextor M402U	DVD LP	MPEG-2	1/2-D1	2.0 → 6.0	16.7		
Plextor M402U	DVD EP	MPEG-2	SIF	2.0 → 6.0	16.7		
CyberLink PP2	SVCD	MPEG-2	480 x 480	→ 2.4	18.4, 21.7	30	
PVR-Plus	SVCD	MPEG-2	480 x 480	2.3			
Plextor M402U	VCD	MPEG-1	SIF	1.15 → 1.5	10.3	70	
PVR-Plus	VCD	MPEG-1	SIF	1.15	10.0		
CyberLink PP2	VCD	MPEG-1	SIF	1.15	10.1	60	
ADS USB4U701	VCD	MPEG-1	SIF	1.15	10.8		
Plextor M402U	HQ	MPEG-4	F-D1	4.0 → 6.0	31.7		
Plextor M402U	Good	MPEG-4	F-D1	3.0 → 6.0	24.2		
Plextor M402U	SP	MPEG-4	F-D1	2.0 → 4.0	16.0		
Plextor M402U	LP	MPEG-4	SIF	1.5 → 4.0	12.2		
Plextor M402U	EP	MPEG-4	SIF	0.7 → 4.0	6.2		
Plextor M402U	Home Theater	DivX	F-D1	4.0 → 6.0	31.7		
PVR-Plus	MPEG-4	DivX	Selectable	Selectable	< 1.0 +		Horizontal striations at F-D1
Plextor M402U	LP	DivX	F-D1	2.0 → 6.0	16.7		
Plextor M402U	Portable	DivX	SIF	0.77 → 4.0	6.7		

to be PC viewing rather than distribution on optical disks. If you'll play back videos only on a PC, MPEG-4 can help you store massive amounts of video on a 4,700 MB disk in digital (mostly not DVD player compatible) format.

## GOAL — Web Page Video Distribution

I tried various methods to get the smallest file possible given a fixed

video run-time. The most aggressive compression via MPEG-2 for a one-minute movie clip was about 3.5 MB per minute. Pinnacle Studio 8's wmf format and MPEG-4 offered similar results. Viewing quality varied among the formats, but if viewed larger than 2" x 2", they all looked pretty bad. Watching .wmf or 1-2 Mbps DivX files on a full screen reminded me of the alien pods growing in the movie *Invasion of the Body Snatchers* — bod-

ies were often an indistinguishable blur, and slowly filled in with resolution if they stood still in the video frame.

Faced with video files that just can't go any smaller, I found humor in the marketing spin the video industry has accomplished. Since nobody would tolerate downloading huge files, a smart marketing person decided to call the never-ending download something else. Hence, we arrived at the concept of streaming video. Instead of "the download aborted," we now accept "the streaming video server got too busy." Amazing how flexible consumers are!

To be fair, streaming video sources are more flexible than downloading static video files, and work well for real-time feeds. For instance, the X-Prize foundation offered live video when Spaceship One succeeded in winning the \$10 million prize last October, and I'm sure other uses will be discovered as more people can receive it. You need a connection that will keep up with the streaming bit rate, but you can start watching the video before it's all downloaded.

## Summary

I've settled on encoding VHS tapes with the K-World VS-L833D PCI card, and Power Producer 2 software package. After it's saved, I edit and re-save files using Visual Studio so I can retain an edited copy on my hard drive. If I want to archive MPEG-4, I convert using MVR-Plus. Lastly, I burn it to DVD with Movie Factory since it offers the most versatile DVD menu construction.

If I want scheduled recordings or MPEG-4, I use the PVR-Plus software. I didn't find any way to easily offer reasonable quality videos from my web page to people with limited download bandwidth. **NV**

## AUTHOR BIO

Brian Mork is a Directed Energy System Engineer at Edwards AFB, and also works on the staff of the USAF Test Pilot School as an Air Force Reservist. He became involved with video editing when trying to synchronize data collected from various devices such as gun cameras, aircraft HUDs, and tracking cameras.



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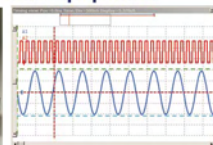
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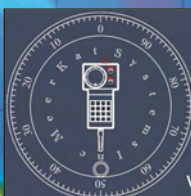
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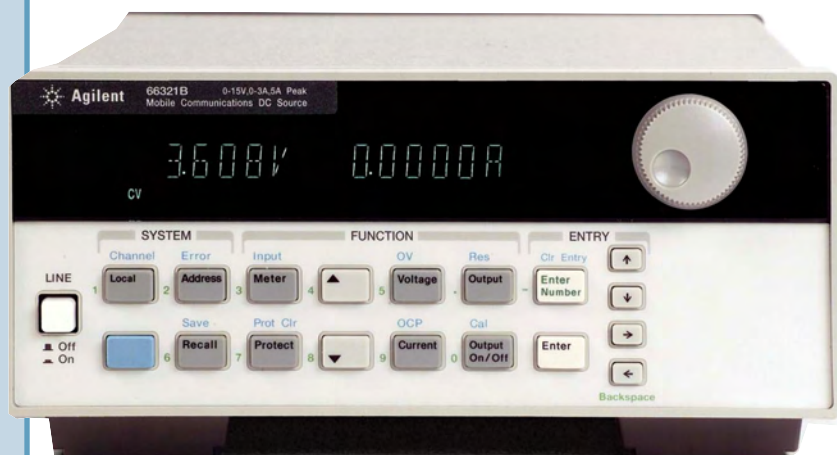


# CONSTANT CURRENT SOURCES

by Vaughn D. Martin

## PART 1

**This two-part, very applications-oriented article first defines a constant current source, and then shows what it can do for you.**



A constant current source (CCS) can supply any output voltage necessary to keep its output current constant, regardless of its load resistance, thus, its name. Theoretically, a CCS supplies a constant current at zero voltage to a short circuit, and tries to supply the same current at infinite voltage to an open circuit. A CCS should have a voltage limit (preferably adjustable) that limits the maximum voltage appearing across its load.

In contrast, a constant voltage source's output current changes to keep the output voltage constant, regardless of its load. You are probably far more familiar with and better recognize constant voltage sources, such as batteries, the AC power line, and laboratory power supplies. Most

electrical energy sources in nature approximate constant voltage sources.

Agilent, the commercial test equipment company formerly known as HP (Hewlett-Packard) still makes CCSs. Several other companies, such as Keithley, also make very sophisticated CCSs (see Figures 1 and 2).

### Regulation

Regulation is the most important specification of a CCS. A CCS' current must remain constant if you want to make extremely accurate resistance measurements. As a "rule of thumb," the CCS's regulation should be a factor of 10 times better than your desired measurement's accuracy.

### Load Voltage Measurement Capability

Measuring output voltage can be a problem when you use CCSs. If you connect a voltmeter directly across the load, the meter impedance shunts the load impedance. This alternate path provided divides the total current sup-

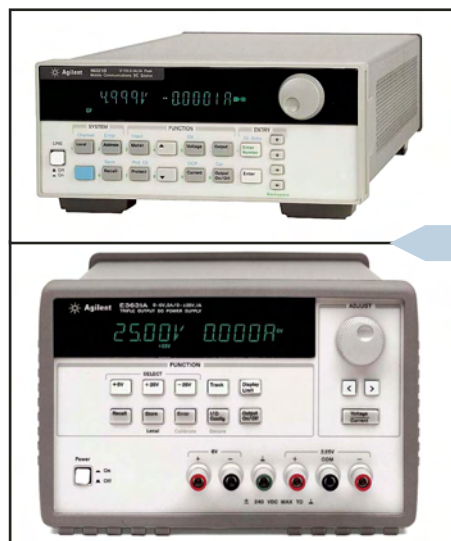
plied from the CCS between the load and the voltmeter. The load then does not receive the previously set value of current, and the voltmeter indicates a lower output voltage than was present before you connected the meter.

For example, if the load impedance is 1 M $\Omega$  (e.g., a load requiring 100  $\mu$ A at 100V) and the meter impedance is 10 M $\Omega$ , the measured load voltage and the current supplied to the load are both decreased by approximately nine percent.

### The Active Guard

It is necessary to provide another method of measuring the load voltage. The method used in the CCS is related to one of the instrument's basic design features — the active guard surrounding the positive output terminal. Because the CCS output voltage is held equal to the guard potential by feedback action, a meter connected to the guard will indicate the output voltage (within a fixed 1 mV offset).

Any current drawn by the meter will be supplied by the guard source and not by the main current supply, thus effectively isolating the meter from the load circuit and eliminating the error just described. The guard typically



**Figure 1**

The Agilent models 66321B mobile communications DC source and E3631A triple output DC power supply — both can serve as constant current sources.

Keithley's Model 6220 DC and Model 6221 AC constant current sources, respectively, with the DC CCS capable of performing pulsed I-V measurements, reducing the likelihood of damaging heat-sensitive devices.

**Figure 2**





**Figure 3**

The Four-Point measurement technique with two leads C1 and C2 comprising a two-wire current source that circulates current through the resistance you are testing. Leads P1 and P2 provide a two-wire voltage circuit that measures the voltage drop across the resistance you are testing.

has a label of "+METER" on the front panel of the CCS.

## Low Output Capacitance

Low output capacitance is essential in a CCS, since excessive output capacitance would cause the high AC output impedance to decrease with increasing frequency, resulting in current transients in rapidly changing loads.

For example, if a diode being supplied by the CCS goes into avalanche breakdown, its impedance suddenly changes. If the CCS has an energy storing capacitor on its output, the sudden change of impedance causes large amounts of energy to be dumped into the diode. This can destroy it!

## Rapid Programming Ability

When you wish to rapidly program the CCS' output current, two critical areas arise: CCS incremental measurements and high speed automated testing. For example, you can commonly measure transistor incremental H-parameters by supplying the device with two current sources: a DC bias current and a small signal AC current that causes incremental changes around the bias point.

By cleverly programming a CCS rapidly enough to supply the AC current, just one instrument can supply both of these currents. This greatly simplifies measurements.

## Approximations to a Constant Current Source

Before CCSs, you had two basic methods: a constant voltage supply with a large series resistor or a constant voltage/constant current (CV/CC) "crossover" supply.

Both of these approximations to CCSs severely limited their use. The

first limited the magnitude of the voltage and resistance required to achieve good load regulation. For example, suppose you wanted to measure a semiconductor's reverse breakdown voltage with an accuracy of five percent.

Typically, your CCS had to supply 1 mA with 50V compliance (equivalent to a 50 k $\Omega$  load resistor). For your desired measurement accuracy, regulation of at least 0.5 percent is necessary. That is, the ratio of the series resistance to the load resistance must be 200:1. This requires a 10 M $\Omega$  series resistor. This resistor and the 50 k $\Omega$  load form a 200:1 voltage divider.

For your desired 50V compliance, the constant voltage source must be 10,000V! This is obviously not practical — and even if such a voltage source were readily available, it would be dangerous and very difficult to control. A realistic value for the constant voltage source might be 500V. To achieve your required 50V compliance, the series resistor would have to be 500 k $\Omega$ . This is load regulation of 10 percent, which is only marginally satisfactory.

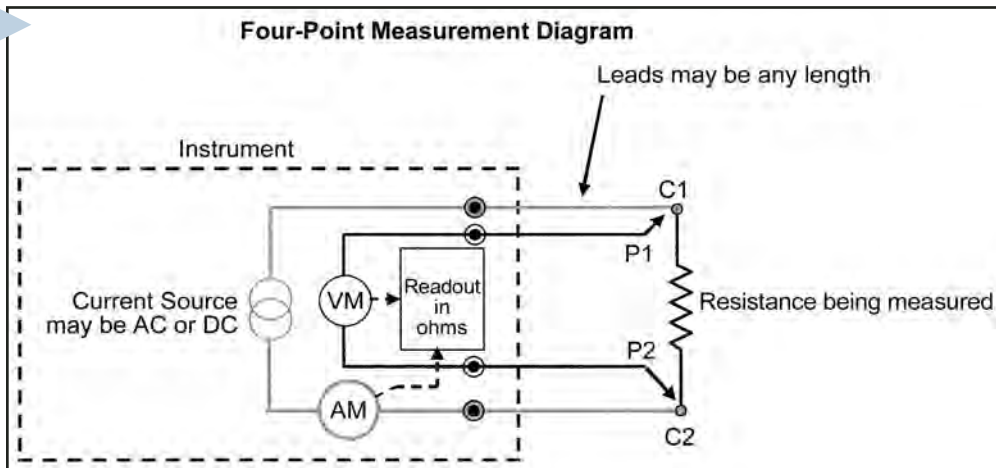
The second approximation to a CCS — that of a CCS crossover supply — has output

capacitance appearing across the supply's output terminals as its limitation. A CCS crossover supply design optimizes its performance as a *constant voltage source*.

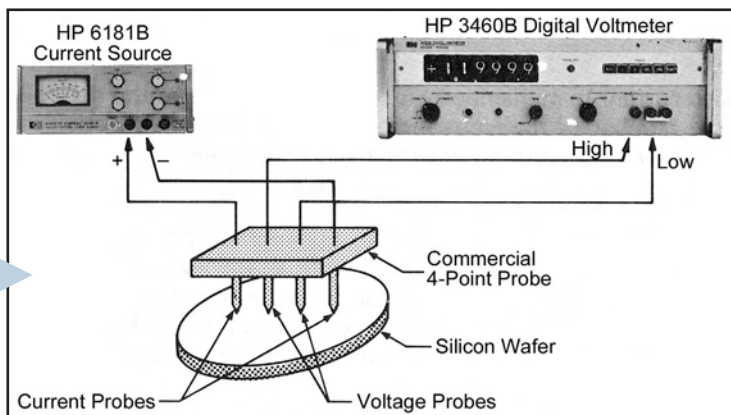
Sacrifices occur in tradeoffs. To assure amplifier stability and freedom from oscillation, this crossover supply's output capacitance is commonly 10 pF or higher! But, as previously demonstrated in our zener application example, even small output capacitances may store enough energy to destroy loads. This capacitance also limits the voltage compliance speed, which prevents rapid programming. Therefore, you can now appreciate why a CCS is so handy, as the following more easily recognizable, less abstract examples will show.

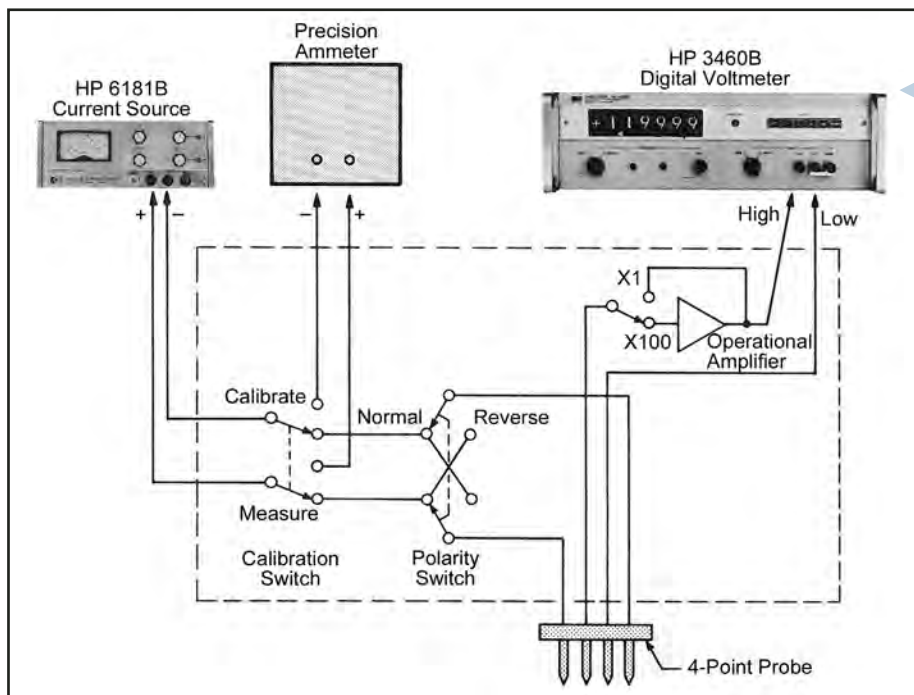
## Applications

Resistance measurements are merely Ohm's Law at work! If you use a known current with an unknown resistance, the voltage drop you measure is directly proportional to the resistance. This reduces resistance measurements to voltage measurements. The very



**Figure 4**  
The Four-Point method of measuring a silicon wafer's resistivity.





The Four-Point method of measuring resistivity, with added sophistications.  
**Figure 5**

contact with the silicon wafer sample using a probe containing four in-line contact points<sup>1</sup>. The outer two contacts supply a constant current through the sample, and the others measure the voltage drop across a section of the sample. Using four probes nullifies the contact resistance error; refer to the definition of the Four-Wire Measurement Technique in the sidebar.

If the current and voltage were at the same contact, there would be an IR drop across the probe-to-sample contact resistance and in the body of the probe itself between the sample surface and the connection to the voltmeter lead. This would cause a significant error when you measure low resistivities (0.0005  $\Omega/\text{cm}$  to 1.0  $\Omega/\text{cm}$ ) with the IR drop approaching the magnitude of the sample voltage.

## Measurement Technique Improvements

There are several minor sophistications that you can include in the measurement. The first is a "calibrate-measure" switch. Figure 5 shows how you can connect an external precision ammeter to the CCS in the "calibrate" position. This allows you to accurately set the current to your desired value.

The second sophistication uses the CCS' voltage limit control. If you apply too high of an initial contact voltage to very thin wafers, you can quite easily break them down. When you set the voltage limit to a value slightly above

high accuracy that you can achieve using this method is the preferred one in the following four applications:

- Silicon Wafer Resistivity (Four-Point Measurement)
- Production Line Resistance Testing, Grading, and Trimming
- Measuring Contact Resistance
- Temperature Measurement by the  $\Delta R$  Method

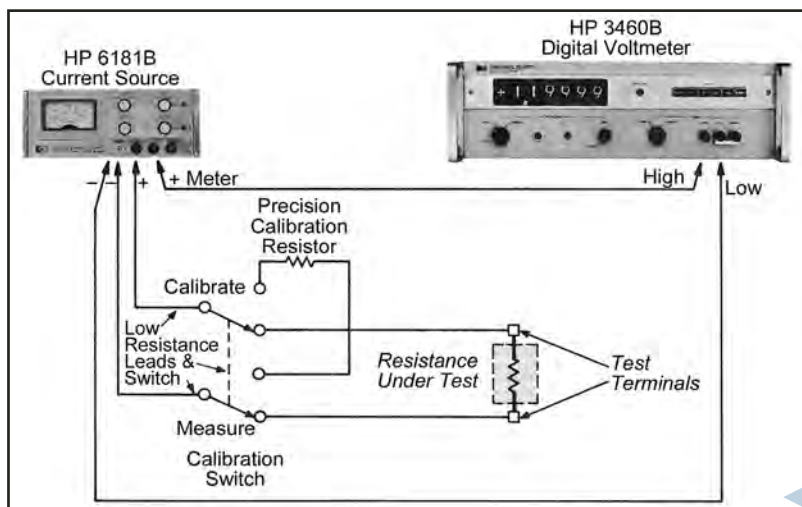
## Silicon Wafer Resistivity (Four-Point Measurement)

This measures the resistivity of silicon slices used in manufacturing semiconductors. It is ideal for the CCS method. Resistivity ( $\rho$ ) is the resistance

in ohms that a unit volume of material, or surface area, offers to the flow of current that you measure in  $\Omega/\text{cm}$ .

One application is determining if a semiconductor process has an impurity, such as boron or phosphorus, working its way into a silicon wafer. This undesired migration changes the electrical characteristics of the silicon. Resistivity which, in this case, is actually the density (concentration) of this impurity at the surface, helps you measure the effectiveness of the diffusion process. (See the Resistivity Defined and Kelvin Measurement Defined sidebars.)

The four-point probe method shown in Figure 4 allows you to make



## Resistivity Defined

Resistivity is the resistance to the flow of current at an atomic level (through either its volume or surface). It depends on the number of free conduction electrons and not on the shape or cross-sectional area of the conductor, like normal resistance does.

Basic resistance measuring setup.  
**Figure 6**

the maximum voltage you expect to measure, you are protecting the samples from the damage that otherwise might occur when the probe first touches the sample.

A third improvement uses a polarity reversing switch you place in the current leads of the probe to allow you to reverse the direction of current flow through the sample. Reversing the current allows you to check the contact between the probe



and the wafer surface for undesired "diode" action. You can also use a range switch on the current source to check the contact condition. If you suspect poor contact due to heavy surface oxide, for example, change the range switch to the next higher (or lower) range. This increases or decreases the current by 10. If the measured voltage does not change by the same factor (within the two

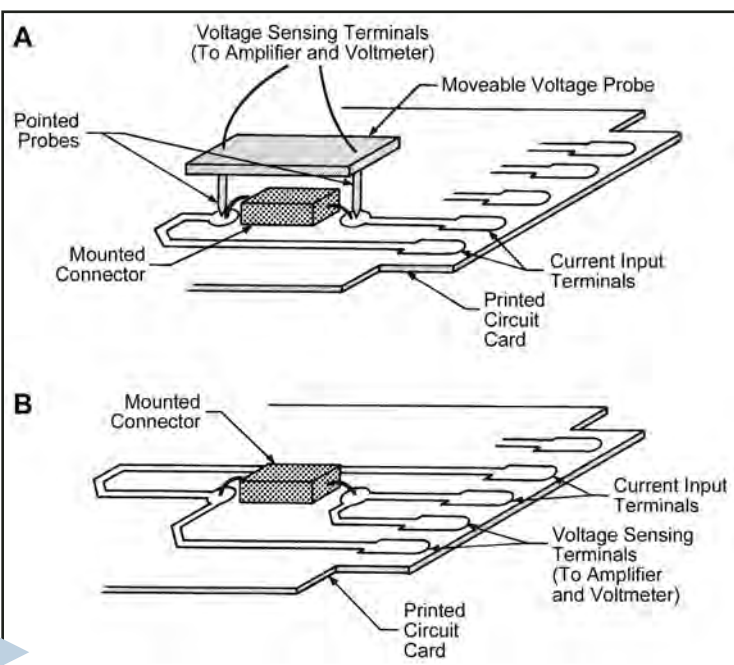
## Kelvin Measurement Defined

The Four-Wire Measurement Technique — more commonly known as Kelvin measurement — is ideal for low resistance measurements since it nulls out the test lead or test interface wiring resistance (see Figure 3). When you are measuring very low resistances of 0.1 ohms or less, analog meters are totally inappropriate because you cannot distinguish these low readings from zero.

A 4-1/2 digit DMM does have 1/100 ohm resolution; however, the connecting leads' resistance, the contact resistance where the leads plug into the meter, and where the leads clip is significant compared to this unknown resistance. Here is where the Four-Wire Measurement Technique is mandatory.

Setup for measuring the contact resistance of crimped connectors.

**Figure 7**



percent range switching tolerance), the probe-to-surface contact is behaving in a non-linear fashion. You should adjust it. Be careful using this checking method at currents over approximately 10 mA because of undesirable heating effects.

Lastly, you can use an op-amp to amplify the probe voltage when you measure very low resistivities. For example, with a sample of 0.005  $\Omega$ /cm silicon and an applied current of 1 mA, the probe voltage is only 5  $\mu$ V — measurement accuracy at this low level is difficult to achieve. If you use a stabilized 100 gain op-amp, your measured voltage would be 0.5 mV (see Figure 5).

## Production Line Resistance Testing, Grading, and Trimming

A typical production line grades surface mount resistors that come packaged on a heavy paper reel with an acceptable tolerance of  $\pm 10$  percent. Set the CCS to provide fixed currents in multiples of milliamperes so the voltmeter reads directly in kilohms or any convenient multiple thereof (e.g., at 0.1 mA, 1V equals 10 k $\Omega$ ).

Figure 6 shows how you connect the voltmeter to the meter terminal of the CCS to avoid the measurement error across the resistance you are measuring. However, since your voltmeter is measuring the CCS output terminals, you must minimize both the resistance of the leads connecting the

test terminals to the CCS and the contact resistance of the calibration switch.

To accurately set the current, you can connect a precision resistor (0.01 or 0.001 percent) across the CCS via the calibration switch and adjust the current for an exact voltmeter reading. You can set the voltage limit control to eliminate high voltages across the test terminals when you remove one resistor and insert another.

## Measuring Contact Resistance

You can easily measure very low resistances, such as contact resistances of switches, relays, and wire connectors with a CCS with the four-terminal (Kelvin) method. This method is the same as the previous one, except that you substitute the contact pair or connector you wish to measure for the chip surface mount resistor (see Figure 5).

Crimped edge connectors are a good example of this. Four-terminal resistance measurements and a cycling oven allow you to evaluate these connectors. Typical initial resistance for this type of connector is 3 m $\Omega$ . A high quality connector will not increase in resistance more than three-fold

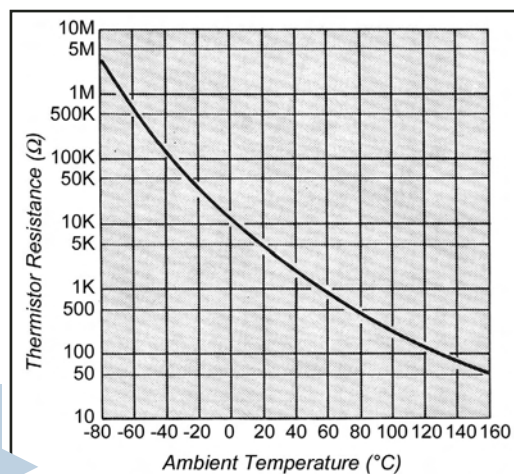
after aging in an oven cycled from -400°F to +1400°F.

Figure 7 shows two ways you can make this measurement. In both cases, you mount the connectors (20 or more) on a PC card by soldering the wires protruding from the connectors to pads on the card. You supply the test current in both cases to the connector through a pair of tracks leading to edge-connector fingers.

In (A), a moveable voltage sensing probe (part of the framework into which the PC card is plugged) contacts the pads to which the connector wires are soldered. Because you achieve voltage sensing directly at the connector, you eliminate the effect of resistance in the current supply leads, and you only measure the connector resistance.

Typical temperature versus resistance curve of a 3 k $\Omega$  thermistor.

**Figure 8**



# Constant Current Sources

Version (B) senses the voltage drop across the connector with a moveable probe you can easily make yourself. This method requires no moving parts. Typical currents you use range from 1 mA to 100 mA; however, be careful with upper end currents causing heating problems if a poorly aged connector has heavy surface film. High test currents may actually break down the film and destroy the resistance value you are trying to measure.

## Temperature Measurement Through $\Delta R$

You can use a CCS to measure temperature by observing changes in resistance. Apply a constant current through a thermistor and monitor the voltage across it via the meter terminal on your CCS. Thermistors, classified according to their resistance at 25°C, are available in a wide range of resistances and tolerances from 0.5 to 10 %. Thermistors with 0.5% tolerances have manufacturer supplied characteristic

## Thermistor Defined

A thermistor is a semiconductor temperature sensor with a repeatable change in electrical resistance as a function of temperature. Thermistors usually possess a negative temperature coefficient, with resistance decreasing as temperature rises.

curves or tables of their values. Figure 8 is a typical curve for a 3 k $\Omega$  thermistor. (See Thermistor Defined sidebar.)

You must consider self-heating of the thermistor when you apply current. Most thermistor data sheets list the dissipation constant (the amount of power in milliwatts required to raise the thermistor 1°C above the surrounding temperature). Typical values vary from 1 to 10 mW/°C. You should limit the power dissipated in the thermistor ( $I^2R$ , where  $I$  is the applied current and  $R$  is the resistance at the measurement temperature) to one tenth of this value for best results. Indirect temperature measurements also use this method. You might want to measure the operating temperature of a winding of a small shaded-pole motor to ensure compliance with an Underwriter's Laboratory safety specification.

First, measure the resistance of the winding at room temperature. Next, heat the motor by running it at full load, stalled rotor, multiplied by the number of hours of operation. Now remove the power from the winding and measure the change in resistance of the winding at set intervals (typically five seconds) until it has partially cooled.

A DVM with a "hold" control is ideal here. Extrapolate this data to yield the resistance of the winding at the instant you remove the power. Fourth, use the equation below to determine the operating temperature:

$$T_{\text{hot}} = 1/K (R_{\text{hot}}/R_{\text{cold}}) + (KT_{\text{cold}} - 1)$$

where  $T_{\text{hot}}$  is the operating temperature in °C,  $T_{\text{cold}}$  is the room temperature in °C,  $R_{\text{hot}}$  is the resistance in ohms at the operating temperature,  $R_{\text{cold}}$  is the resistance in ohms at room temperature, and  $K$  is the temperature coefficient of resistivity of the winding at room temperature. For both copper and aluminum (the two most commonly used materials),  $K = 0.0039$ . You can find values for other materials in any engineering handbook. **NV**

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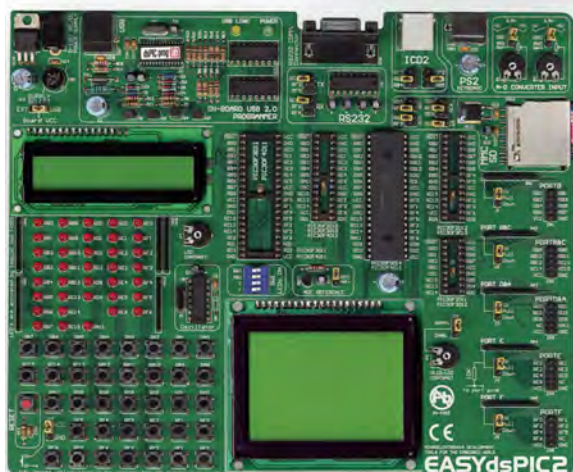
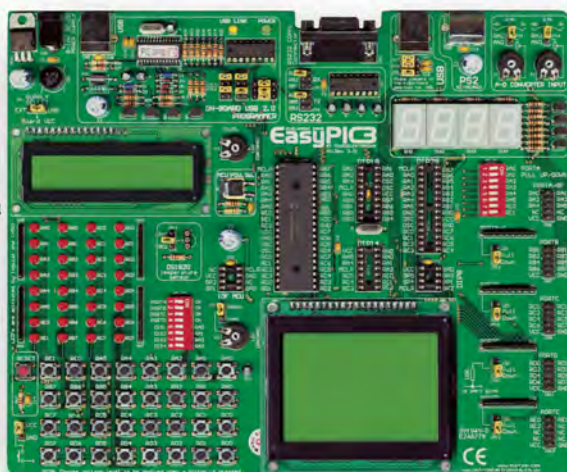
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# GETTING STARTED WITH PICs

## THE LATEST IN PROGRAMMING MICROCONTROLLERS

■ BY CHUCK HELLEBUYCK

## GOING BEYOND 31 COMMANDS

**THE FEEDBACK TO MY ARTICLES TELLS ME this series on programming Microchip PICs is a success. Based on loads of email, I've helped many readers get back in the electronics game and comfortable programming microcontrollers. That is a reward in itself and is enough for me because many years ago, I was there, too. That success, though, also invites its detractors.**

I've had a small percentage of emails asking why I don't teach "C" programming or assembly. I've had people email me details about other "better" microcontrollers or even "better" programmers than the EZPIC programmer I've presented earlier. The common theme though seems to be that I'm out of touch or doing a disservice because I focused on the Basic language in these articles. I've heard all that before, too.

I'll be the first to admit I'm no expert. I'm just trying to help beginners get started. It's my dream that every person realizes they are capable of creating that special electronic gadget using a microcontroller. When the Personal Computer first came out people asked "What do you do with it?" Eventually, people with very little knowledge of a PC were writing programs in Basic language that launched an industry. Early killer apps such as Visicalc (the first Excel) made the Apple II computer an industry standard.

Eventually programming languages evolved and so did the hardware. C, Pascal, Fortran, and other languages were soon available. If you were into programming, you were in heaven. Jobs were created that involved programming only. Companies were launched that only sold software.

Microsoft — the biggest of them all — started out by offering the Basic language. A totally new profession was launched but it all started with a microchip and I never forgot this fact.

Where does it say that a user who writes a program in Basic that gets programmed into a PIC and runs that custom temperature datalogger or home alarm system isn't also a real program? If it works, who cares how you got the 1s and 0s into the chip. If, after a while, you want to move from Basic into other languages currently (and I stress currently) accepted in industry, then you have a great platform to build on. I write these articles for electronics hobbyists and also mechanical engineers, chemical scientists, basement technologists, and kids just getting started. In other words, anybody who is willing to learn can become a PIC programmer.

Are there better chips out there for your application? Maybe. Are there better PIC programmers out there? Yeah, if you can afford to pay more. If my articles get you started and you eventually move to C and better chips and better tools, then all I ask is don't forget those behind you.

The help I received from those more experi-

■ FIGURE 1. The full version of the PICBasic Pro compiler.



enced was priceless, so I'm passing it back on to you, the reader. With all the tools, books, components, and software dedicated to Microchip PICs out there now, there is no reason to pay someone big bucks to create a prototype of that great invention in your head. Do it with a PIC.

### BASIC OPTIONS

Speaking of tools, if you have been using the 31-command-line free sample version of the PICBasic Pro compiler, by now you probably are ready to write bigger and more complex programs or even use different PICs. The obvious next step is to purchase the full version of the PICBasic Pro compiler (Figure 1). With it, you can write programs as big as your PIC chip memory can handle. You can program eight pin PICs, such as the 12F675 or even the new 18F PICs with up to 64K of memory. All this comes at a cost though.

The full compiler retails for \$249.95 and even though I discount it at my website ([www.elproducts.com](http://www.elproducts.com)), it's still a lot of money to shell out if you are not sure how much you will use it. It's like having a tool in your tool box. Once you have it, you wonder how you did jobs without it. There are other options, though.



■ FIGURE 2. The Basic Atom.



## BASIC ATOM

One of my favorite Microchip PIC options is the Basic Atom. I'm sure you've seen the Atom modules in *Nuts & Volts* which have the same footprint and look of the BASIC Stamp modules, but what many people don't realize is at the heart of an Atom module is actually a Microchip PIC16F876A or PIC16F877A chip with a self-programming bootloader inside. It's a PIC (Figure 2) that you can purchase separately from the module and use in your PIC16F877 or 876 circuit.

The story of the Basic Atom is interesting. It was created by a couple of guys in Michigan, only a few miles away from where I live. They started out by creating a PICBasic Pro compiler competitor called the MBasic compiler. It sold well, but had a lot of early bugs. Because it was only two guys, handling all the tech support became a problem. They realized that a lot of the tech support involved the differences with the various PICs. If they could focus on just a few key PICs, they felt they could make a solid compiler with the time they had.

The BASIC Stamp, being so popular, became the footprint they tried to emulate, but instead of using the fetch and function BASIC Stamp method, they took their MBasic compiler and combined it with a custom bootloader program for the PIC16F876 and PIC16F877. These PIC chips have the unique ability to program their own internal memory with a small program hidden in their program memory called a bootloader. It's kind-of like having an operating system on your PC prior to loading a program you really want to run.

The features of the MBasic compiler were carried over to the Atom, so this gives the Atom access to all the PIC features, such as timers, A/D, interrupts, etc. The Atom sold well right from the start since it offered higher speed and more memory. To me, though, the big feature was the fact that I could program the Atom PIC chips and plug them into any PIC16F876 or 877 development board.

If I designed my own development

board with a serial communication circuit, similar to the RS232 circuit I used in the March issue, then I could program the Atom PIC 16F876 or 877 right in-circuit without having to remove the PIC over and over again.

## IN-CIRCUIT DEBUGGER (ICD)

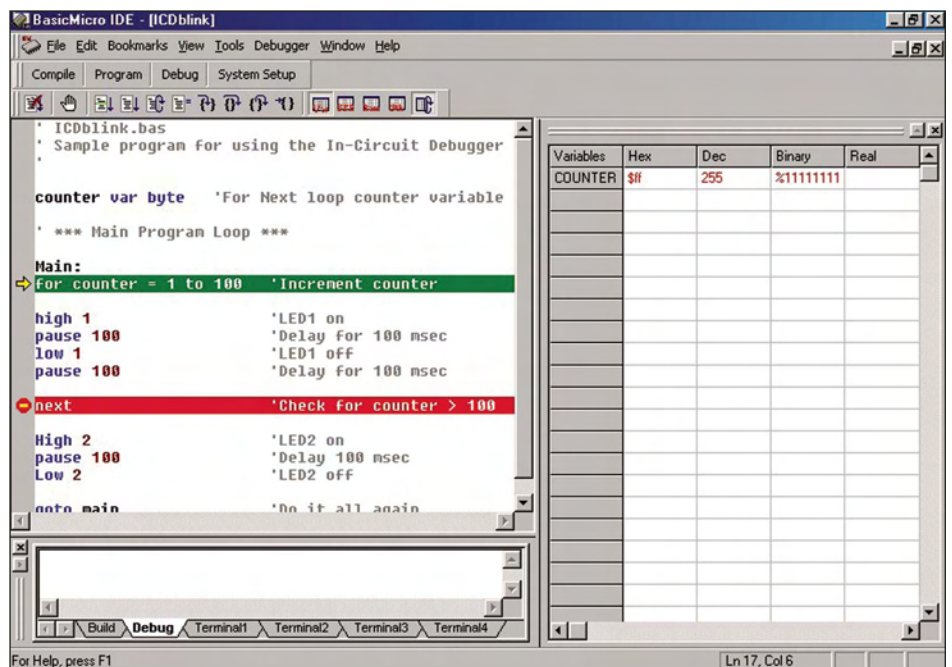
This is what locked me into the Atom. The MBasic compiler had an in-circuit debugger program (Figure 3) built in that allowed you to run your program in slow motion command by command. This made it easy to catch errors because you could see the changes in the RAM (variables), special function registers (timers, Portb, etc.), and even run sections of program in real time, but stop at a breakpoint. It was like having a Basic language driven emulator and it was included for free and in the Atom software.

So, why would I be so excited about all this and why am I telling you this? It's because they give away the Atom compiler software for free. The only catch is you have to buy the Atom PIC chips from them or an authorized reseller — like my site. The Atom chips cost \$20 each, so if you are going to build a 100-piece design, then using the PICBasic Pro compiler will quickly pay for itself over the Atom, but most read-

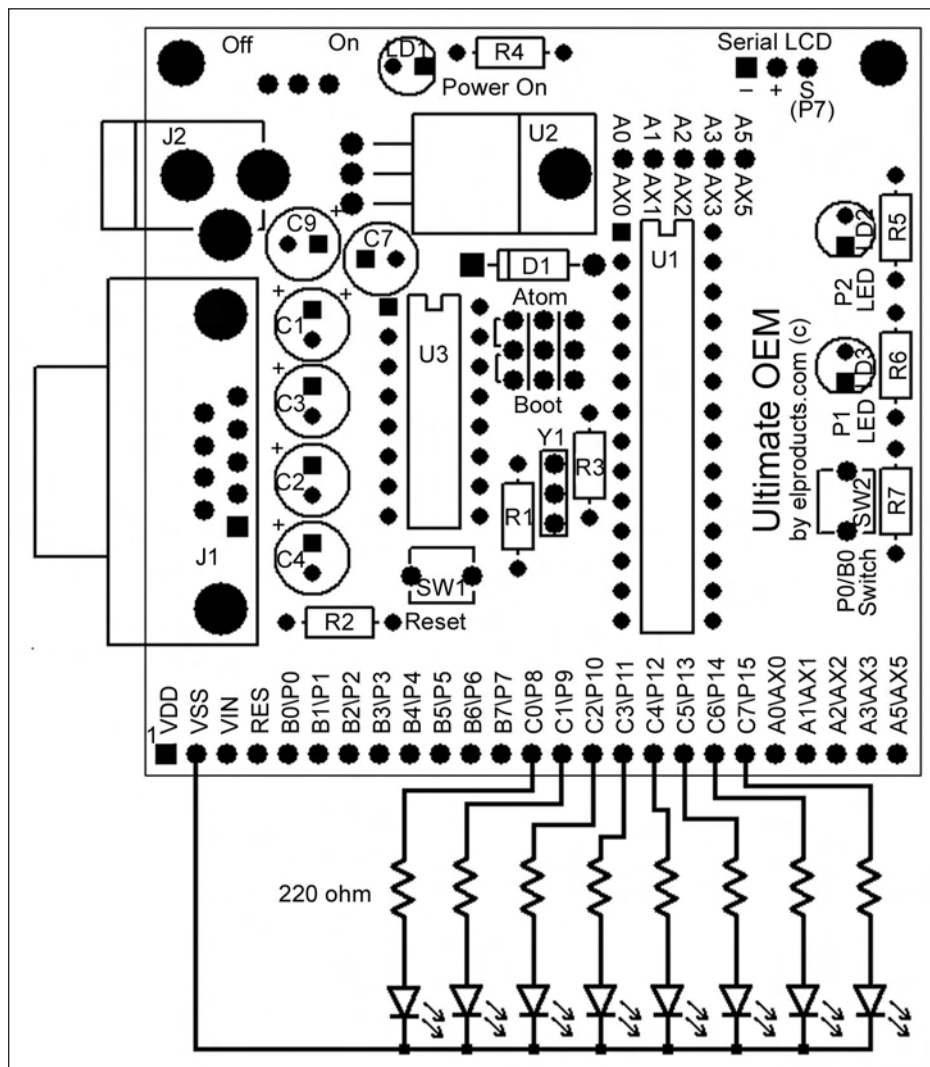
ers are just experimenting or building a few prototypes. For \$20, you get a full-featured compiler with in-circuit debugger and features PICBasic Pro doesn't have, such as floating point math and much simpler access to timers and other special function registers.

Here is the best part of all. They kept most of the syntax of the Basic commands compatible with the BASIC Stamp and PICBasic Pro, so moving a program from the Stamp to PICBasic to the Atom is quite easy. I often create with the Atom using the ICD to prove out the idea and then move to PICBasic Pro for higher volume applications.

The Atom has been used by so many people, it's been proven to be a very solid compiler. I recently released my second book — this time on the Atom — titled *Programming the Basic Atom Microcontroller*. You should be able to find it at the *Nuts & Volts* bookstore, my website, and a few other resellers. My point to all this is that you still don't have to spend more than \$50 to program PICs beyond the 31 command line limit, just like my January article pointed out. I've even put some of my Atom-based modules on my website that are designed for the beginner that wants a complete development module with the programming interface built in. I even have my BasicBoard with LCD, LEDs, switches, speaker, and potentiometer



■ FIGURE 3. The in-circuit debugger program screen shot.



■ FIGURE 4. The block schematic.

## 1s AND 0s

However you achieve the binary hex file of 1s and 0s — using Basic, C, or Assembly — doesn't really matter if you get that prototype working and can have fun along the way. Microchip offers several different programmers and development tools that work with the MPLAB environment. I hope to cover a few of those, as well. Professional PIC software engineers have access to in-circuit emulators that allow you to plug a multi-pin probe into your PIC board and step through your assembly code using MPLAB, similar to the way the Atom ICD works. Learning how to use the Atom ICD, thus, prepares you for using the MPLAB.

So, to answer those who emailed me about why I focused on programming PICs in Basic, it's because the readers appreciate it and it is the best path for the beginner. I have a dream that someday purchasing PICs and other components will be as popular as going to Home Depot to buy the parts to build something at home. Only time will tell.

## SIMPLE PROJECT

I wanted to include a simple project for those people who look forward to building something every month. Here is a project from my Atom book on driving a bank of LEDs to scroll back and forth like that car on the TV show *Knight Rider*. I have a very similar project in my PICBasic book. The program in Listing 1 will work with both the Atom and PICBasic Pro as written. The only difference is the PICBasic version assumes a 4 MHz resonator is used while the Atom assumes a 20 MHz resonator. The program controls eight LEDs connected to PortC. The LEDs are wired with the cathodes commonly connected to ground. A high at the I/O port turns an LED on and low turns it off.

## HOW IT WORKS

The software program controls the LEDs and flashes them one at a time in a continuous scrolling motion of light. To understand the software, let's step

built in. It's really a great chip to design around and deep down it's still a PIC.

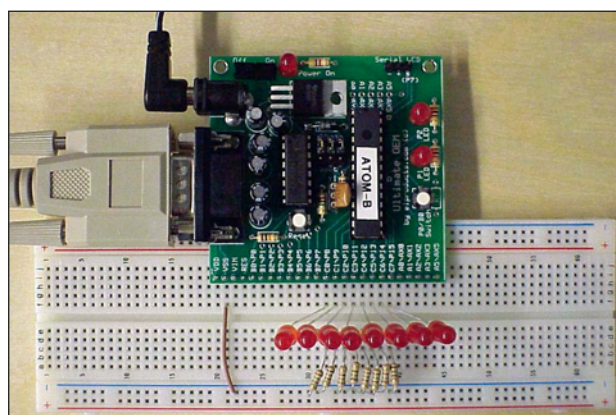
## OTHER SOFTWARE

There are other options out there, as well. Other Basic compilers, such as CHBasic and Proton, cost around the same as PICBasic Pro. There are C

compilers, such as CCS and Hi-Tech, which are also at least as expensive as PICBasic Pro. Some of these compilers offer freeware limited versions, as well. You can even download the outstanding MPLAB development suite from Microchip's [microchip.com](http://microchip.com) website. It's completely free and is designed for the assembly language programmer.

In future articles, I will cover assembly language because I find moving from Basic to assembly to be a fairly easy path for those so inclined. I also hope to cover C at some point because readers may want to see some of that, but that will be further down the road.

■ FIGURE 5. The assembled project.





through the major sections of code.

The top section states: `*** Define Program Variables *****`. This is where the variable gets defined. A single variable is established and given the simple nickname of "x." The program will use that later as a general storage space for the FOR-NEXT loop command counter.

Program variables need to have their size defined. In this example, "x" does not need to be larger than 255, so a byte size will do.

```
` *** Program Variables ***
x var byte
```

After the variable definition, the main program loop is entered. The description line `*** Main program loop ***` begins this section and it's quickly followed by the main: label.

```
` *** Main program loop ***

main:
```

This label defines a location within the program where the main section of code begins. Under this label is where the LEDs are sequenced. The HIGH and LOW commands are used to turn the LED on (HIGH) and off (LOW). Because this program has to repeat the same function for each LED, the program could have a bunch of HIGH and LOW commands. That would work, but it would also take up more than 31 lines.

To simplify the program, the FOR-NEXT command will be used. The FOR-NEXT command creates a small loop where everything between the line that starts with FOR and the line that starts with NEXT is rerun a specified number of times. For example, look at the code section below.

```
for x = 8 to 15
high x
pause 10
low x
pause 10
next
```

The section of code starts with the FOR command followed by a simple little math type statement, `x = 8 to 15`. What this means is that every time this list of commands is executed, increment the variable x by one starting with 8 and ending at 15. This is known as a FOR-NEXT loop.

The value of the variable x is

actually tested at the NEXT command line. If x equals 15, the program leaves the FOR-NEXT loop and moves on to the commands following the NEXT command line. If x does not equal 15, the program control jumps back to the FOR line and x is increased by 1. This allows you to write a chunk of repeating commands without having to write them over and over again.

In this loop of code, notice how the HIGH and LOW commands share the variable x. Each time the program runs through the FOR-NEXT loop, a different LED should be lit. By using the variable x after the HIGH and LOW commands, a different LED is turned on and then off.

The value of x must match up to the pins connected to the LEDs. In this case, because the LEDs are connected to Port C, we can use 8 through 15 as the FOR-NEXT counter values while also using them as the pin variable in the HIGH or LOW commands.

This project uses a very short delay time between the HIGH and

LOW commands. The intent is to make the light scroll forward quickly. Notice that I only said forward. That's because this FOR-NEXT loop only lights LEDs 8 to 15. It does not reverse the direction and light 15 through 8. That requires a separate FOR-NEXT loop. The next section of code is very similar and is another FOR-NEXT loop. In this section, though, the FOR-NEXT loop counts down instead of counting up.

```
for x = 15 to 8 step -1
high x
pause 10
low x
pause 10
next
```

That change of counting direction is done with the step -1 added to the FOR command line. The step -1 directs the FOR-NEXT command to add a -1 (negative 1) to the value of x each time through the loop. The FOR command line starts at 15 and goes to 8. It's the opposite of the first FOR-NEXT loop.

The purpose of counting the opposite direction is to make the LED light

## LISTING 1

```
*****
`*   Name       : chap6code.BAS                               *
`*   Author    : Chuck Hellebuyck                             *
`*   Notice    : Copyright (c) 2005 Electronic Products       *
`*               : All Rights Reserved                         *
`*   Date      : 3/31/05                                       *
`*   Version   : 1.0                                           *
`*   Notes    : Scroll 8 LEDs                                  *
`*               :                                           *
*****

` *** Program Variables ***
x var byte ` FOR-NEXT loop variable defined

` *** Main program loop ***

Main:      ` Main loop label
for x = 8 to 15 ` Loop 8 times thru code
high x      ` Turn on next LED
pause 10    ` Delay 10 milliseconds
low x       ` Turn off LED
pause 10    ` Delay 10 milliseconds
next        ` Is x = 7 yet?

for x = 15 to 8 step -1 ` Loop 8 times in negative direction
high x                  ` Turn next LED on
pause 10                ` Pause 10 milliseconds
low x                   ` Turn off LED
pause 10                ` Pause 10 milliseconds
next                    ` Is x = 0 yet?

goto main              ` Jump to main and do it again

end                    ` Stop if the program gets here
```

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scroll back from the far right LED to far left LED, thus completing the back and forth scrolling motion.

After the FOR-NEXT loops are complete, the last command is the GOTO MAIN command line. It loops the program back up to the "main" label so it can run over and over again.

To make sure the program does not get lost, the END command is added at the bottom. If this command is ever encountered, the program will stop running until the reset switch is pressed or power is removed and reconnected.

## HARDWARE

For the hardware, I cheated and used my Ultimate OEM module (Figure 5). This module can be easily switched from an Atom module to a PICBasic module with a chip change. It brings all the PIC pins out to the main header, so to reproduce this with a bare PIC just requires a resonator, MCLR pull-up resistor, 5V, and ground. Then wire the LEDs to PortC. The block schematic is shown in Figure 4 and the project assembled in Figure 5.

## CONCLUSION

No series of articles can be everything to everybody, and *Nuts & Volts* was kind enough to give me this opportunity to reach the beginners out there. If you have any questions, comments, or complaints, just email me at [chuck@elproducts.com](mailto:chuck@elproducts.com). It's your feedback that lets me know what direction to take. If you find a really cool PIC product, let me know about it. It may lead to more interesting articles in the future. Also, send me your project pictures. Other readers may like to see them. **NV**

## SOURCES

■ *Atom* — Basic Micro  
[BasicMicro.com](http://BasicMicro.com)

■ *PICBasic Pro* — microEngineering Labs  
[melabs.com](http://melabs.com)

■ *PicBasic Pro and Atom* — Chuck Hellebuyck's Electronic Products  
[elproducts.com](http://elproducts.com)

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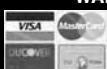
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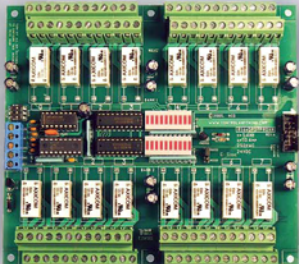


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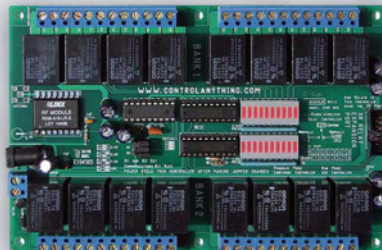
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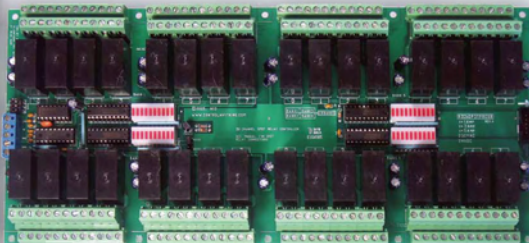
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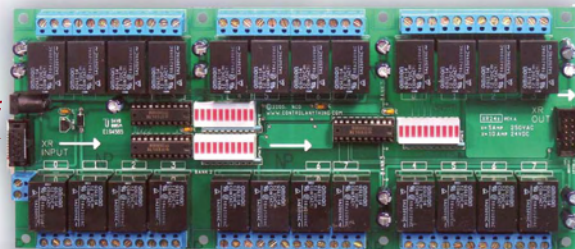
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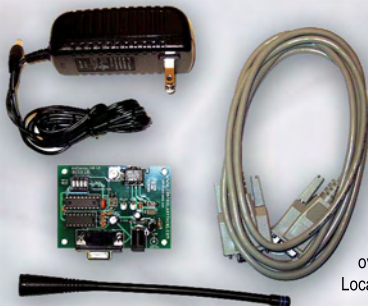
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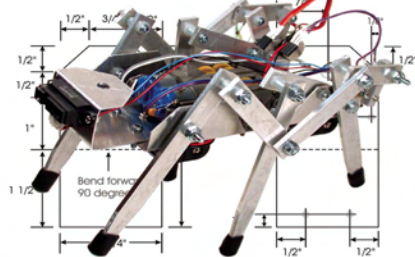


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# PERSONAL ROBOTICS

## UNDERSTANDING, DESIGNING & CONSTRUCTING ROBOTS & ROBOTIC SYSTEMS

■ BY PHIL DAVIS Co-written by Joe Stramaglia

## ZEN AND THE ART OF ZIGBEE: PART 1

**DURING THE PAST COUPLE OF YEARS,** in Mike Keesling's regular *Personal Robotics* column, you may have seen my name mentioned a couple of times with respect to Shelob — a multi-legged robot using reverse kinematics and also the Balancing Sphere robot. Unfortunately, Mike has decided to retire from writing this column, and offered to pass the privilege on to me. Robotics is a hobby and a study that I happen to feel pretty passionate about so, when I was offered the opportunity, I was happy to jump at it. My intent for the next year or two is to bend your ear about some of the new and exciting technologies which you might apply to your very own personal robot.

I've chosen Zigbee as my first topic for *Personal Robotics* because ... well, because it's cool. In this issue of *Nuts & Volts*, we'll begin a general discussion on what Zigbee is, its basic functionality, where to get it, and the associated software. Parts 2 and 3 will be in subsequent issues. In Part 2, we will follow a project in which a simple peer-to-peer Zigbee connection will be used to control a robot, and Part 3 will attempt to show a more complex mesh topology.

Zigbee is one of the new technologies designed to enable Wireless Personal Area Networks (WPAN) based around the new and emerging IEEE 802.15.4 standard. As such, Zigbee has great potential for incorporation into personal robotics for control purposes, for telemetry, and for just plain programming, to name a few applications.

In the Personal Robotics context, you should think of a WPAN as your home, your backyard, or perhaps your office space. Imagine sitting at your PC and communicating to your robot, telling it to stop, start, turn left, etc., and your robot reporting back various

pieces of information — perhaps the direction it is pointing if it has a compass or, if using odometry, the encoder counts from the wheels.

For an idea of how much 'real estate' this will take up on your robot, take a look at Photo 1 for a typical Zigbee transceiver with a quarter as a reference to size.

So, what are some of the identifying characteristics of Zigbee?

- Designed to work in the 2.4 GHz or 868/928 MHz bands.
- 2.4 GHz is great for penetrating walls and ceilings.
- Has a relatively low data rate — less than 250 kps.
- Range is in the order of 250 feet or less.
- Has really low power consumption — months, if not years.
- Has several different network topologies.
- Automatic connection of devices (think robots).
- Ability to add or remove devices (think robots).
- Allows Ad Hoc networks.

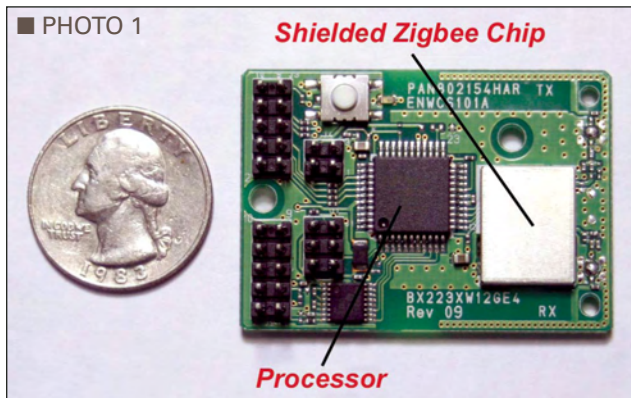
- It's cheap.
- It's small.

At the risk of being just a little boring, let's discuss some of these characteristics in more detail.

The 868 MHz band is a European standard and the other two are typically used in the US. Most people will recognize them from the bandwidths used in common cordless phones. As such, it also makes sense that they penetrate walls, floors (basements), and ceilings fairly well, which is just what we want for communicating with our robot.

The transmission speed is very good, although 250 kps is not what we are used to in today's world of cable bandwidth, it is more than ample for communicating with robots, perhaps not for sending real time video, but certainly for voice, small still pictures, and any kind of control we can think of. At 2.4 GHz, the 250 kps is probably good for 20 to 25 K bytes per second — not bad for cheap RF robot-to-robot communication.

In addition, because the 'stack' is quite small, initiation of a transmis-





sion or receipt of a message is exceptionally fast and for this context, give me that over bandwidth any day.

All readers with battery operated robots will love to hear that Zigbee is something of a power miser, as well. The power consumption is almost negligible during transmission and receiving, and even less when Zigbee is idle, dozing, or hibernating. Transmission and receiving uses as much as 37 mA, whereas idle uses 500  $\mu$ A, doze 35  $\mu$ A, and hibernate as little as 2.3  $\mu$ A. Even in the hibernate mode, the chip still responds to attention.

So much for all these numbers, but what does this actually mean for your robots? Well, you could take a Zigbee device and, depending on usage, it might last months or even years on a coin-shaped calculator battery.

The range of Zigbee is an interesting thing in itself and you might say it depends on the specific topology which is in use. Certainly, if the most simple network connection is in use (peer-to-peer), then the absolute overall range is in the 250 feet or less arena and 90 feet has been proven indoors (hmmmm, that will cover most homes). However, this range may be 'virtually' extended if, for example, a 'mesh' topology is used, as we will discuss later.

A Zigbee network can be simple and complex at the same time; this mostly depending on the *nodes* which are in use. You can set up three 'node' types within your network:

- *The PAN Coordinator* (PANC, Personal Area Network Coordinator).
  - Starts and 'owns' the network.
  - Allows other devices to join.
  - Provides addresses and saves messages until they can be delivered.
- *The Router*.
  - Does not own the network, but routes messages.
  - Scans to find a network to join and provides addresses.
- *The End Device*.
  - Does not own or start a network.
  - Communicates with a single

other device.

- Scans to find a network to join.

On top of this, a Zigbee device may belong to one of two classes of device:

- FFD — *Full Function Device* which allows it to be a Coordinator or a Router Node.
- RFD — *Reduced Function Device* which means it can only be an End Device Node.

Whew! Having gotten through that, we can now look at some of the topologies which Zigbee allows us to construct.

The absolute simplest topology is a peer-to-peer involving two devices. Take a look at Figure 1. This is a subset of the star topology, which we'll discuss next. Of these two devices, one must be a PANC and the other may be an End Device. One way to look at this particular net is as if it were a point-to-point serial connection, only without a cable. The maximum distance the two nodes may be apart is approximately 250 feet.

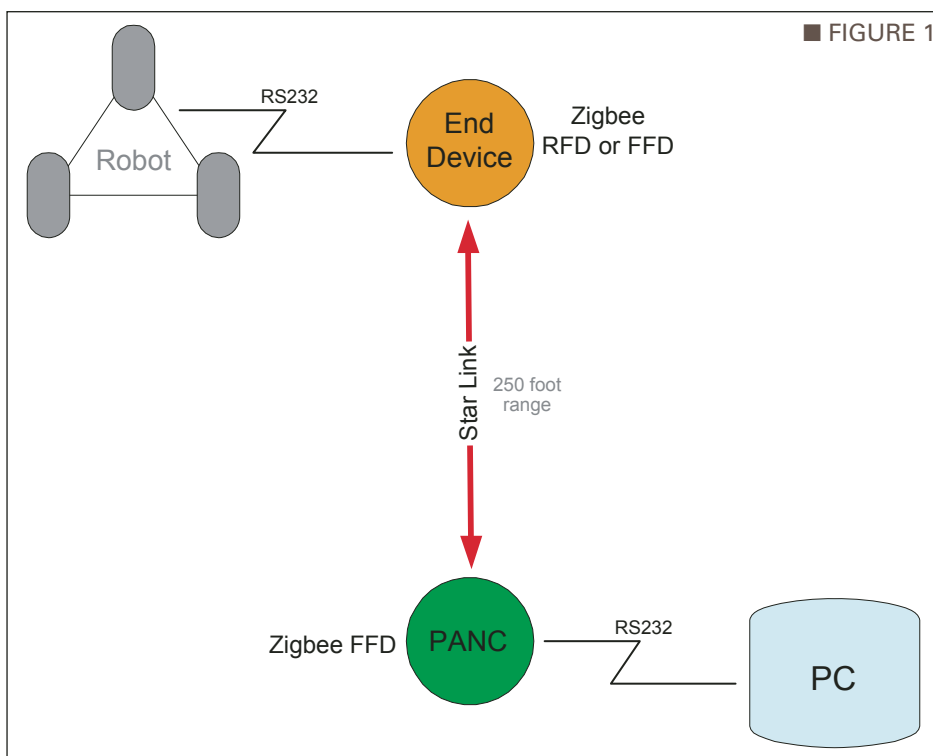
We can now imagine our PC with the PANC Node and the robot with the End Device Node communicating

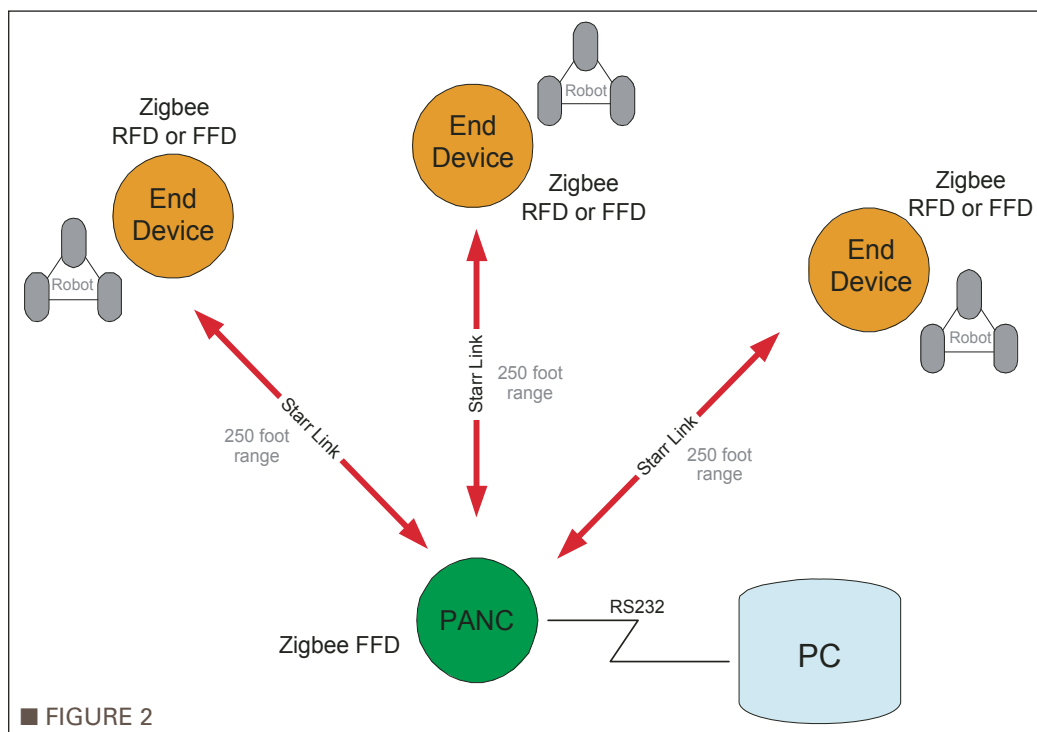
across the living room floor, the robot obeying commands entered at the PC relaying back status information, such as battery charge level.

The next level of topology is an extension of the simple peer or peer network — the star (see Figure 2). The star still has at its center — the PANC — but may have a number of End Device Nodes (up to 64K) with which it communicates. The PANC may communicate with any of the End Devices, however, each End Device may only communicate with the PANC and not with each other.

In this case, we might have a number of robots, each with an End Device communicating with the PANC attached to our PC. From the PC, we might address each, in turn, issuing control commands. The maximum range would again be approximately 250 feet in any direction.

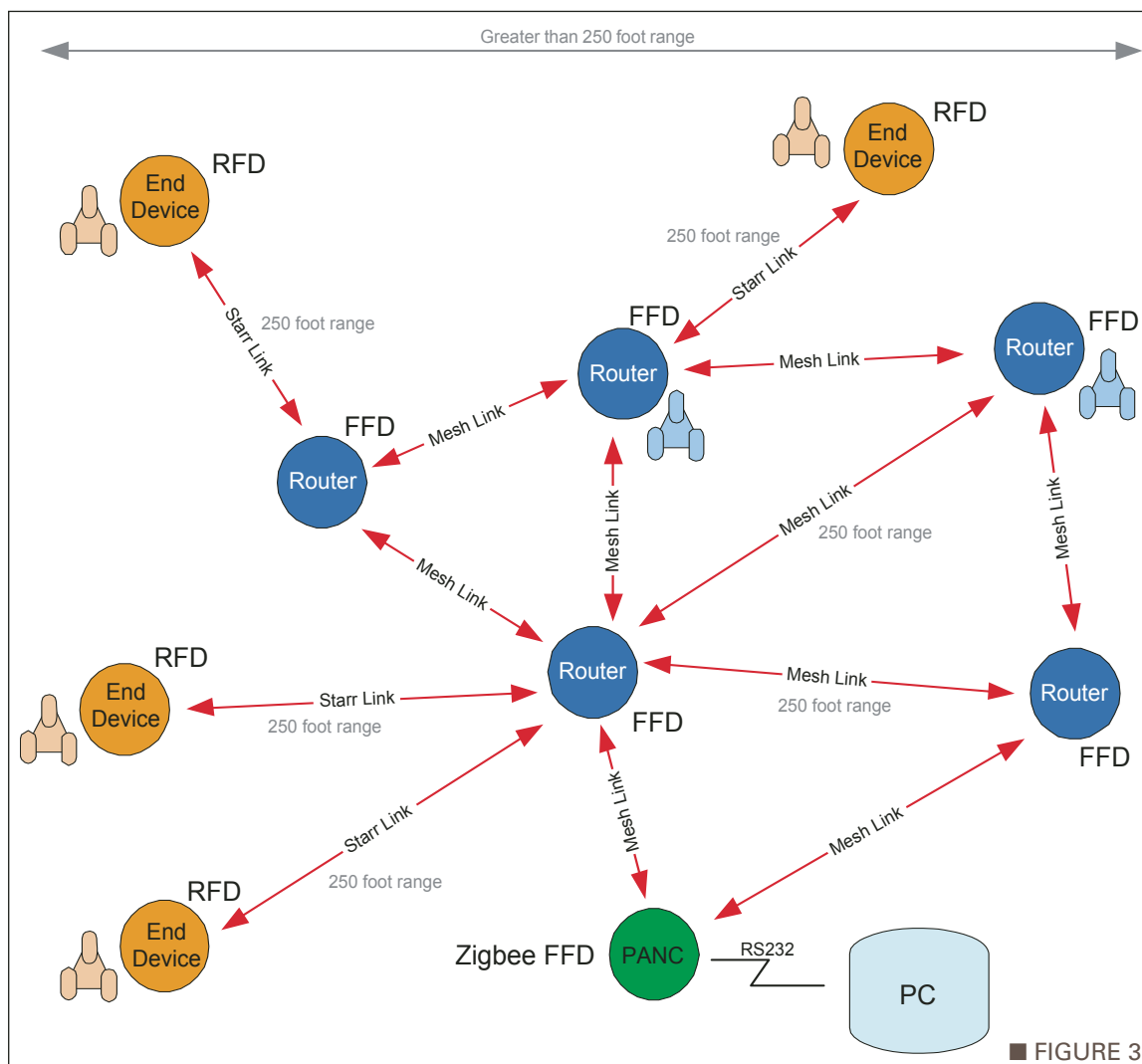
This is most likely the topology a roboticist would use, as it is simple and allows for many robots to be connected to a central PC or, indeed, a 'head/lead' robot. For the sake of completeness, we will look at mesh topologies (see Figure 3) (though there are cluster or tree topologies, as well). The main advantages a mesh network will bring are extension of





range and communication path redundancy.

For the first time, the Mesh topology requires the use of the Router Node. This node's function is to connect together, into a 'mesh' all three types of Nodes, allowing the network to spread across a larger physical area and to allow for multiple communication paths. This function provides for increased range so you are no longer limited to 250 feet, but to the distance of the furthest connected node. Wow. It also provides for redundancy in communication. For instance, if a device were to drop out or its path to a specific router were blocked, an alternative path might be found.



Imagine having 'router nodes' scattered around your office, home, or yard for the sole purpose of 'mesh' topology and providing a network for your robot to wander around in. Perfect for your robotic lawn mower and vacuum cleaner.

In addition, Zigbee nodes establish the network automatically or connect to the network automatically; there is nothing to do except switch on the robot or robots and communication will be established. Similarly, if using a mesh topology, robots may be switched on or off at will and the network will be created.

In the grand scheme of things,



## RESOURCES

■ The Panasonic Zigbee Comm Module is available from: [www.panasonic.com/industrial/components/modules/mod\\_rfm.htm](http://www.panasonic.com/industrial/components/modules/mod_rfm.htm)

■ The Freescale Sard board is available from: [www.freescale.com/webapp/sps/site/prod\\_summary.jsp?code=ZRP-1&nodeId=01J4Fs25657103](http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=ZRP-1&nodeId=01J4Fs25657103)

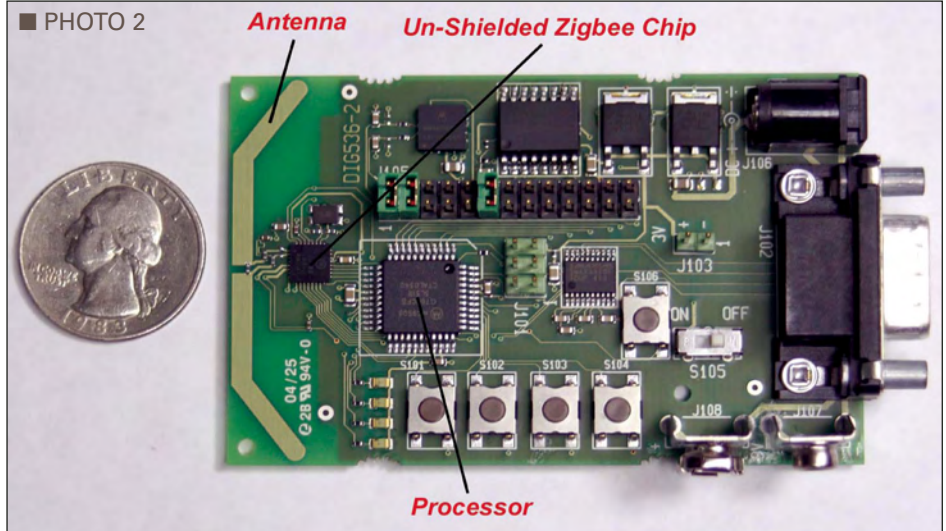
■ The limited, but very functional Freescale metrowerks development software may be downloaded free of charge from: [www.freescale.com/webapp/sps/site/overview.jsp?nodeId=01272694011135](http://www.freescale.com/webapp/sps/site/overview.jsp?nodeId=01272694011135)

■ General Zigbee resources: <http://zigbee.org/en/index.asp> or [www.ieee802.org/15/pub/TG4.html](http://www.ieee802.org/15/pub/TG4.html)

Zigbee is relatively cheap and, although production and use has by no means reached maturity yet, a node from Panasonic costs about \$25 and will most likely be cheaper in the future. A node is also of a size which will fit into most small robots, for example, the Panasonic Node is 1.9 inches by 1.4 inches (see Photo 1).

There are currently several manufacturers producing Zigbee chips, boards, and development kits. In Parts 2 and 3 of *Zen and the Art of Zigbee*, we will look at the Panasonic Zigbee Comm Module, the Freescale Sard (Sensor Application Reference Design) boards (see Photo 2), and the Freescale

■ PHOTO 2



MetroWerks development software.

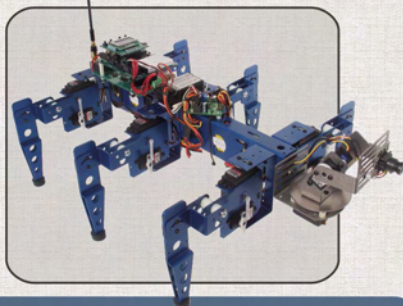
I thought I would end Part 1 with a few thoughts to start you thinking about some of the cool things you might do with Zigbee. If you look closely at Figure 3, you will see that some of the FFD Zigbee devices have robots associated with them. There is no reason why you can't have a router passing messages and also consuming messages to control a robot. RFD devices can only talk to FFD, however, since FFD devices can talk with other FFD devices, you can have your robots send messages to each other.

How cool is that!?! All your robots can chat with each other, perhaps send "come over here" messages or "danger, danger stay away" messages.

Next month, we will show a practical application of a peer-to-peer topology network along with some real world software which will allow some simple commands to be sent to a robot and status to be received. We'll also discuss and demonstrate the physical connection too, along with the development environment and a simple application. Hopefully, this will be enough to get you started with your own project.

Bear in mind that this article sketches the functionality and capabilities of Zigbee and for greater in-depth knowledge, you should spend some time reading through the Zigbee resources you will find on the Internet. **NV**

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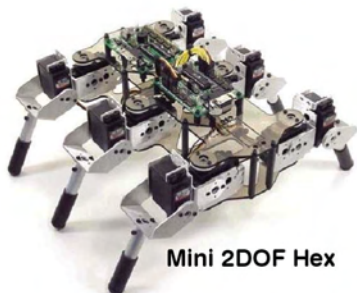
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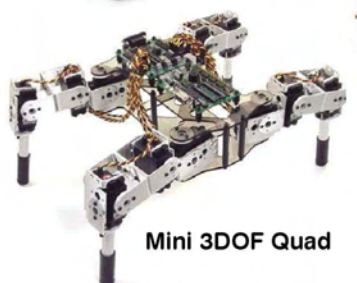
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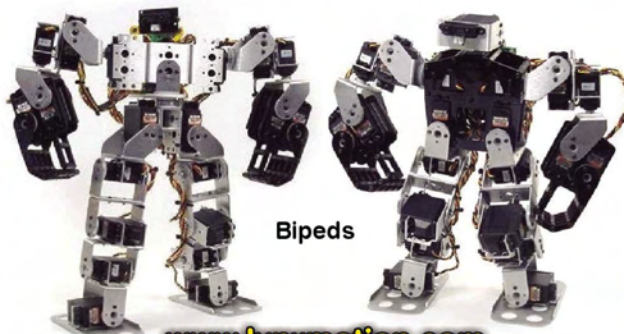
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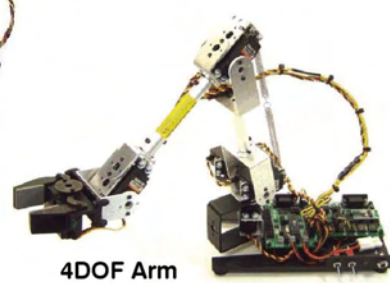
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■ BY PETER BEST

## ARM YOURSELF WITH PHILIPS MICROCONTROLLERS

**IN THE PREVIOUS PAIR OF DESIGN CYCLE COLUMNS, we explored the nuances of the Freescale MC68HC908MR16. This month, we're going to up the ante a bit and jump out of the eight-bit microcontroller universe and warp into the 32-bit microcontroller sector of the microcontroller galaxy.**

**T**his time around, the object of our affection is the Philips LPC2100 family of 32-bit ARM7 microcontrollers. In this text, we will focus specifically on building some LPC2106 and LPC2136 ARM7 hardware from scratch. Once the hardware is assembled, I'll walk you through some functionality testing and introduce you to some of the hardware and software tools you'll need to program and debug the ARM7 microcontrollers.

When we're confident that all of our ARM7 hardware design work has been validated, we'll look at what it takes to write some code to access the features of our newly crafted piece of 32-bit hardware. I'm not going to assume (that turns you into a donkey) that you know anything about ARM microcontrollers. With that, let's begin our design process by gaining an understanding of the basic ARM architecture as it applies to the Philips LPC2100 family of ARM microcontrollers.

### THE LPC2106

Although we will be designing one-half of our ARM7 support hardware around the LPC2106, we could also drop the LPC2104 or LPC2105 into a very similar — if not identical — design. The LPC2104, LPC2105, and LPC2106 are pin-to-pin compatible and are all based on the 16/32 bit

ARM7TDMI-S CPU.

If you're wondering where the 16-bit functionality resides, the ARM7TDMI-S CPU core can run in what is termed THUMB mode, which is a code efficient 16-bit mode of operation. I'm going to stick with the 32-bit ARM mode in our scratch-built projects. So, we won't be employing THUMB mode in any of our code designs.

Compared to standard eight-bit microcontrollers, the LPC2100 ARM7 devices are Flash and SRAM rich. All of the aforementioned LPC2100 ARM7 variants come out of the box with 128KB of Flash. The LPC2104 contains 16KB of SRAM and the LPC2105 houses 32KB of SRAM. We're designing with the Big Daddy of the bunch, as the LPC2106 is packing 64KB of SRAM on top of the 128KB of Flash.

The large amounts of Flash and SRAM are complimented by the ARM7 CPU's speed. The ARM7TDMI-S CPU core is supported by a 128-bit wide memory interface and an accelerator subsystem that can execute 32-bit instructions at clock speeds up to 60 MHz. The LPC2100 devices are based on Reduced Instruction Set Computer (RISC) operating principles, which makes the instruction set and the hardware that processes the instruction set simple in comparison to Complex Instruction Set Computer (CISC) architected microcontrollers.

Most of the time, when it comes down to efficiency in computing systems, simpler is better. In the case of the LPC2104, LPC2105, and LPC2106, the previous statement holds true.

A cursory look at Figure 1 will tell you that the LPC2106 achieves its blazing speed by tying all of the ARM7 CPU subsystems together with high speed busses. Standard microcontroller crystals are used to feed the input of the LPC2106's PLL (Phase Locked Loop), which is used to multiply the base crystal oscillator frequency.

In addition to the standard microcontroller reset, crystal oscillator, and external oscillator inputs, the LPC2106 implements an industry standard JTAG interface, which allows external applications to access the LPC2106's internals via a piece of integral JTAG hardware. The LPC2106 can be debugged and programmed using the microcontroller's JTAG pins.

The LPC2106 can also be programmed by activating the on-chip In-System Programming (ISP) and In-Application Programming (IAP) boot-loader firmware. The LPC2106 Boot Loader is used in conjunction with the LPC2106's ISP subsystem and UART0 to program the LPC2106.

Programming Flash program memory locations using IAP is performed under user program control. In either mode — ISP or IAP — the LPC2106 on-chip Boot Loader



supplies the programming interface to the LPC2106's on-chip Flash program memory.

The LPC2106 is big on memory and speed. So, you would expect it to also be big on peripherals. Many of the eight-bit microcontrollers multiplex the serial interfaces. In that this is a Philips microcontroller, and Philips invented I<sup>2</sup>C, you can be sure that a dedicated and by-the-book-fully-functional I<sup>2</sup>C hardware interface is provided on the LPC2106. As Figure 1 shows us, the LPC2106's dedicated I<sup>2</sup>C interface logically leaves room for a dedicated SPI serial interface.

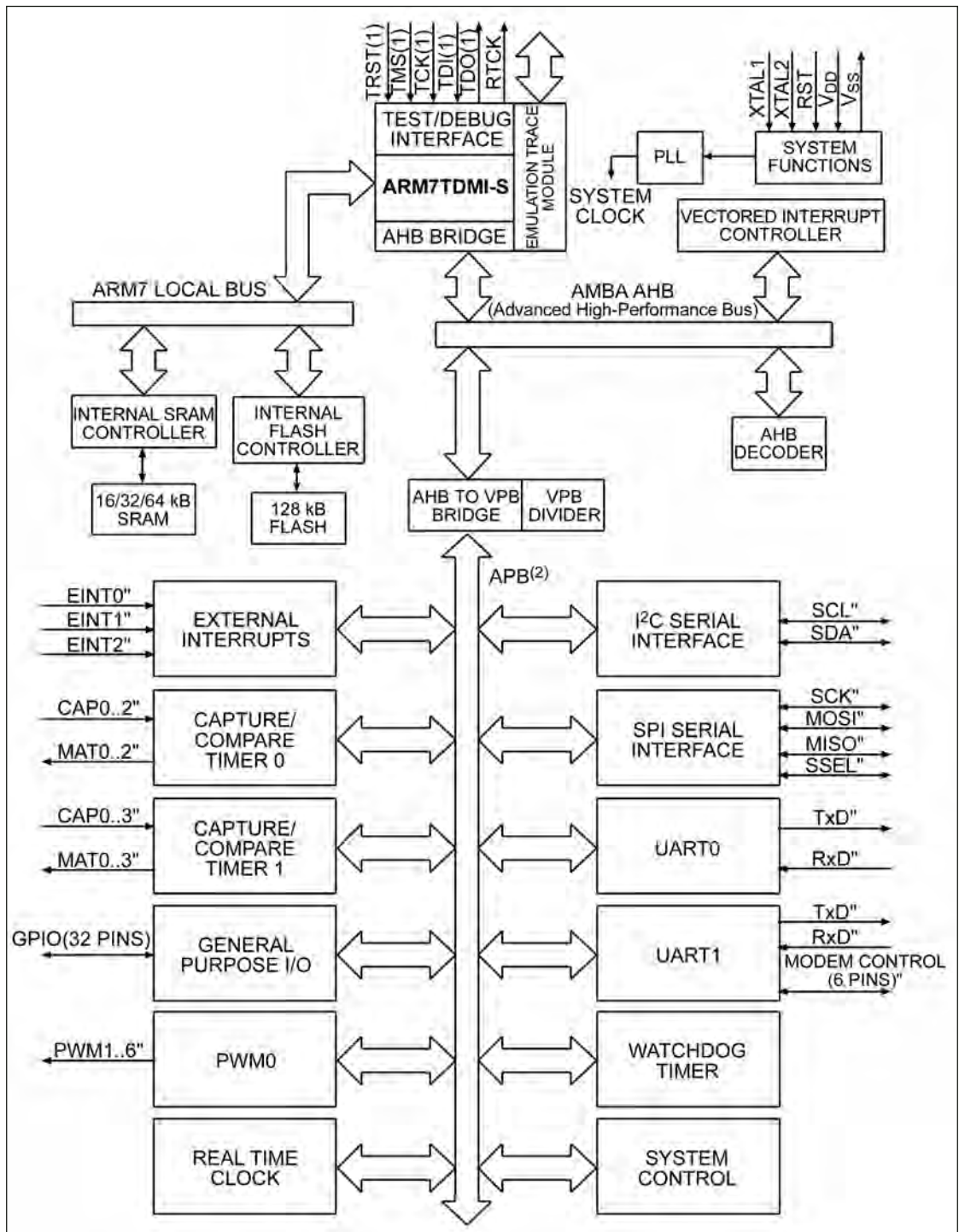
Everything else that you would normally associate with any eight-bit microcontroller can also be found as a feature of the LPC2106. The LPC2106 microcontroller build includes a pair of UARTS and timers with capture/compare capability, a six-channel PWM subsystem, a real time clock, a watchdog timer, and a really neat vectored interrupt controller. Note the absence of analog-to-digital conversion circuitry on the LPC2106.

Electronic devices require some sort of power source to operate and the LPC2106 is no exception. The LPC2106 thus far has been big

on everything. As you would expect, the LPC2106 has big power needs, too. However, don't confuse big for bad here. The normal eight-bit microcontroller runs on a single voltage rail. The LPC2106 requires a pair of separate power levels. The LPC2106 CPU core feeds from a +1.8 VDC power source, while the LPC2106's I/O subsystems need a +3.3 VDC power rail.

The LPC2106's "big" power requirement is in the number of required power rails only and in unison with the pair of LPC2106 low power modes allows the LPC2106 to operate efficiently at very low power consumption levels. The LPC2106 also interoperates easily with legacy +5 VDC systems as most of its I/O pins are five volt tolerant.

Okay, now we have a pretty good



■ **FIGURE 1.** Getting a handle on the LPC2106 isn't so bad once you break it down into its component parts. Before we're done with this device, we'll touch on most everything you see in the figure.

idea about the hardware design points associated with the LPC2106. However, we're also in the early

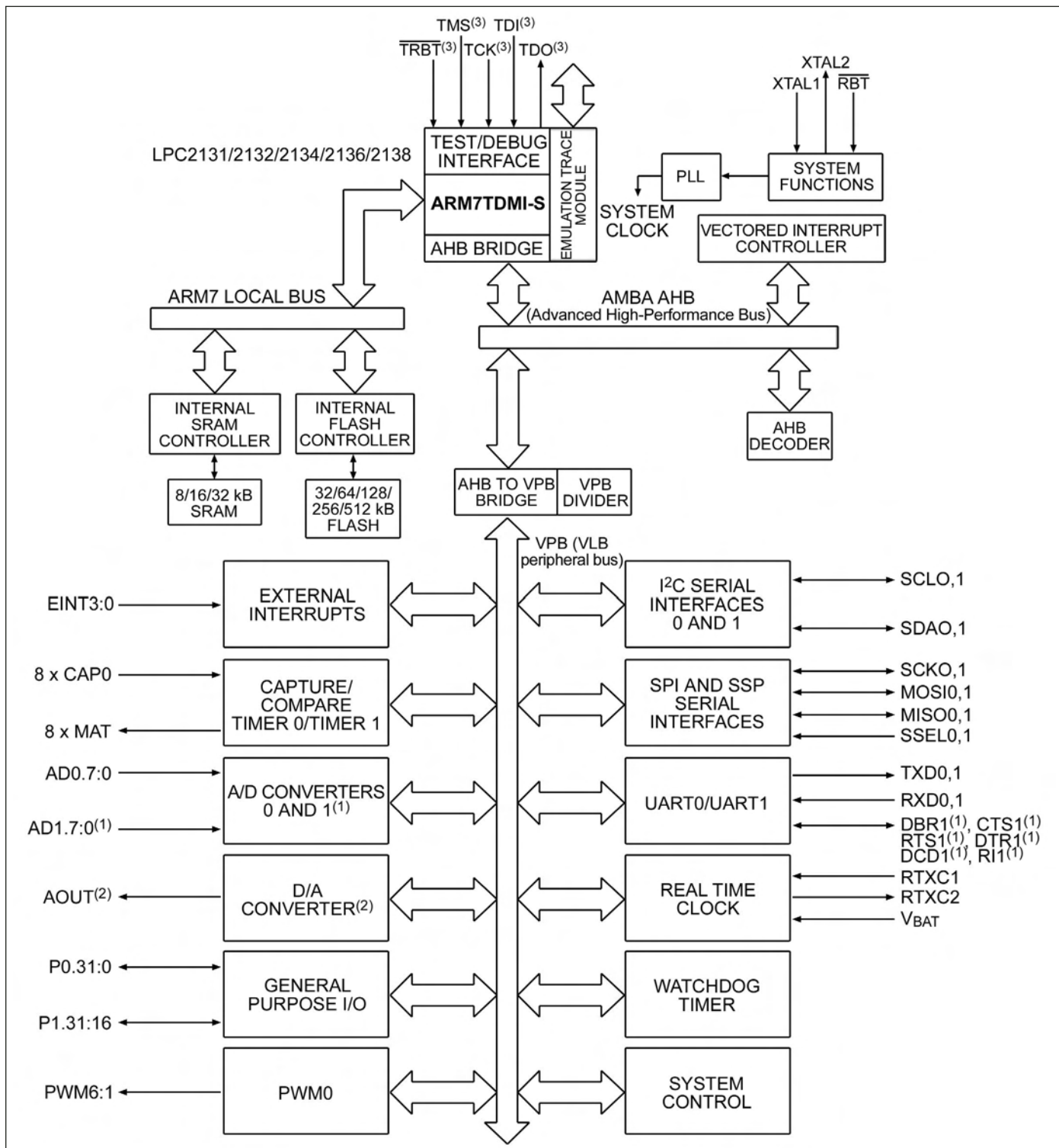
■ **FIGURE 2.** The top components shown in this figure are pretty much the same as what you saw in Figure 1 for the LPC2106. The difference in the LPC2106 and the LPC2136 are evident in the peripheral area. I particularly like the analog-to-digital component.

design stage for another Philips ARM7 variant — the LPC2136.

## THE LPC2136

One of the really neat things about Philips LPC21XX ARM7 micro-controllers is that you can transfer knowledge that pertains to one of the

LPC2100 variants to any of the other members of the LPC2100 family. Everything you've learned about the LPC2106 can be applied to the LPC2136. Both the LPC2106 and the LPC2136 are based on the same ARM7TDMI-S CPU and the 128-bit wide memory interface and accelerator architecture are also present within





■ **PHOTO 1.** This is a bird's eye view of the LPC2106 adapter board. Note the three .1  $\mu$ F bypass capacitors mounted on the bottom side.

the LPC2136. In fact, the only major differences between the LPC2106 and the LPC2136 are the number of peripherals and the power requirements.

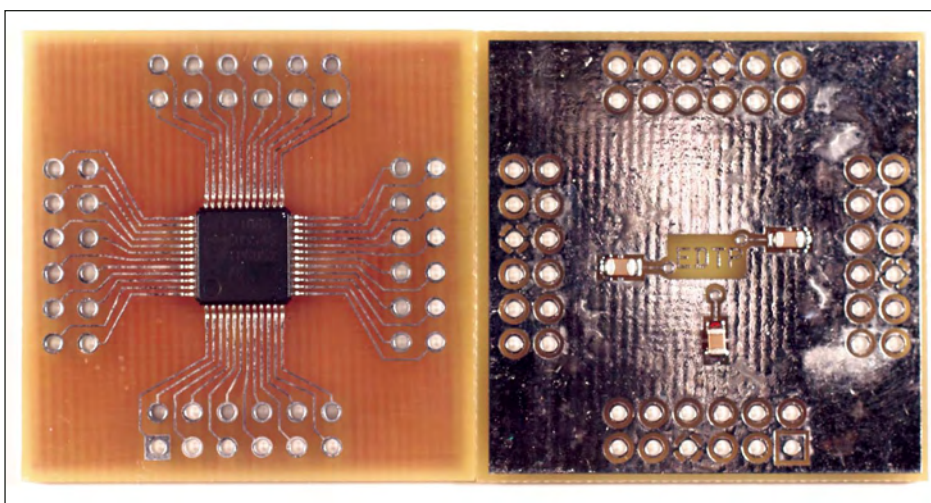
Figure 2 shows us that the LPC2136 is a larger microcontroller in terms of peripherals, SRAM, and Flash storage. The LPC2136 isn't the Big Daddy here and has a big brother — the LPC2138 — which carries 512KB of Flash and 32KB of SRAM. The LPC2136 matches the LPC2138's SRAM size, but only houses half of the LPC2138's available Flash program memory.

The give and take between the LPC2106 and the LPC2136 lies in the LPC2106's larger SRAM size and reduced peripheral count versus the LPC2136's smaller amount of available SRAM and increased peripheral count. This offset of SRAM versus peripheral count correlates with the first rule of embedded computing which states that nothing is free. If you want more peripherals, you must give up something else.

In this case, that something else is SRAM. As you can see in the LPC2106, the first rule of embedded computing works in the opposite way as peripherals are sacrificed for additional SRAM. This give and take is a good thing, as it produces multiple variants of the LPC210X and LPC213X microcontrollers, which allows for more cost effective designs.

The LPC2106 is a 48-pin device. Since Figure 2 shows us that the LPC2136 has 16 more general-purpose I/O pins and pairs of I<sup>2</sup>C, SPI, and analog-to-digital converter interfaces, it would be logical to deduce that the LPC2136 is a physically larger part. The extra peripheral general I/O interfaces push the LPC2136's pin count to 64. Note, also, that the LPC2136 supports an on-chip digital-to-analog converter

■ **PHOTO 2.** Here's a shot of the LPC2136 adapter board top and bottom. The far right bottom capacitor is an 0805 SMT 10  $\mu$ F at 6.3V tantalum that is filtering the  $V_{ref}$  pin. The rest of the capacitors are .1  $\mu$ F 0805 SMT devices, which are acting in the power supply bypass role.



subsystem. Another advanced feature of the LPC2136 is the battery-backup capable real time clock.

Many of the hardware design points that exist for the LPC2106 are common to the LPC2136. However, we must take the battery-backable real time clock of the LPC2136 into account if we plan to use it. Also, there is no need for a +1.8 VDC power source for the LPC2136, as it only requires a +3.3 VDC power source.

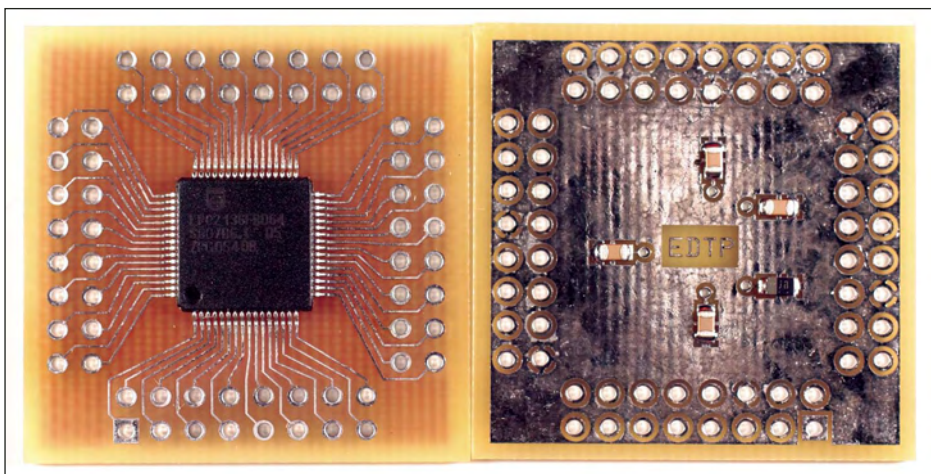
We'll get to know the LPC2106 and the LPC2136 internals better when we begin the coding phases of our ARM7 designs. So, let's attack the hardware design points and build up some ARM7 hardware.

## FABRICATING ARM7 MICROCONTROLLER SYSTEMS

We won't be using custom print-

ed circuit boards at the system level in this installment, as you may want to create your own flavor of the LPC21XX designs I'm about to present to you. With that thought in mind, I've decided to use some prototype boards from other EDP products that contain +3.3 VDC power supplies and ready-to-go RS-232 serial ports. Once we've verified the basic operations of the ARM7 parts, I'll put the final designs down onto some professional printed circuit boards, which I will make available to you via the EDP Electronics website.

Now that I've chosen to use cast-away prototype boards, the first obstacle we have to negotiate is how we will mount the fine-pitched LPC21XX devices. The LPC2106 is tiny and its 48 pins are positioned equally around seven square millimeters. The LPC2136 is equally difficult to breadboard, as it is not much larger with its 64 pins being



equally spaced around 10 square millimeters.

Since I'm using a printed circuit board that wasn't designed specifically for LPC21XX parts, we'll have to resort to some sort of custom adapter for the LPC2106 and LPC2136 micro-

controllers. After some pondering as to how to present the LPC21XX's pins, it didn't take long for me to pull out the printed circuit board CAD program and draw up some boards. My ARM7 microcontroller adapter solutions for 48-pin and 64-pin LPC2XXX devices are shown in Photos 1 and 2.

The top side of my PCB adapter in Photo 1 is supporting an LPC2106. The bottom side of the LPC2106 PCB adapter, which is also shown in Photo

1, holds the three .1  $\mu$ F power supply bypass capacitors (C1, C2, and C3 in Schematic 1), which are all tied to a common ground plane at their grounded terminals. Each of the LPC2106's four ground pins ( $V_{SS1}$ ,  $V_{SS2}$ ,  $V_{SS3}$ , and  $V_{SS4}$ ) are also tied together via the LPC2106 PCB adapter's ground plane.

Bypass capacitor C1 is tied across the LPC2106's +1.8 VDC power pin and ground, while bypass capacitors C2 and C3 are servicing the LPC2106's +3.3 VDC pins. This arrangement of power planes and bypass capacitors makes easy work of integrating the LPC2106, as only a single ground connection and a pair of power line (1.8 VDC and +3.3 VDC) connections feed all of the LPC2106 power points.

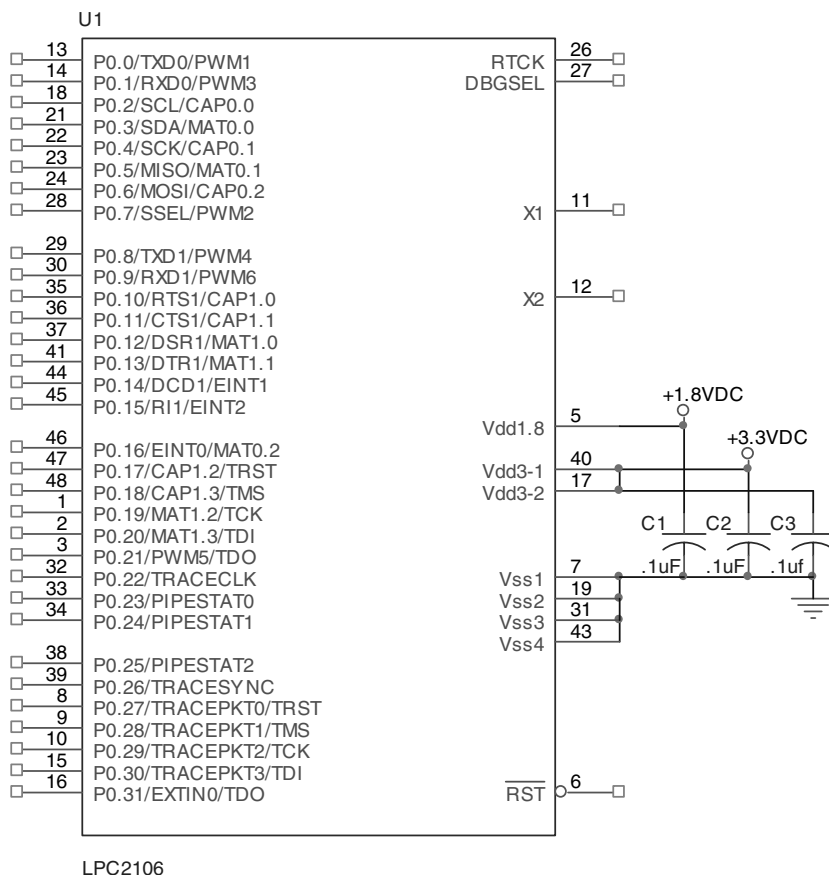
Photo 2 details the top and bottom sides of the LPC2136 PCB adapter. The LPC2136 PCB adapter design is identical to the LPC2106 PCB adapter design as far as thought goes. Bypass capacitors C1, C2, and C3 (depicted in Schematic 2) take care of the LPC2136's +3.3 VDC power pins ( $V_{dd1}$ ,  $V_{dd2}$ , and  $V_{dd3}$ ) with all of the power supply bypass capacitor's opposite ends tied to the LPC2136 PCB adapter's ground plane.

The analog power pin ( $V_{ddA}$ ) is bypassed with capacitor C4. There is no +1.8 VDC

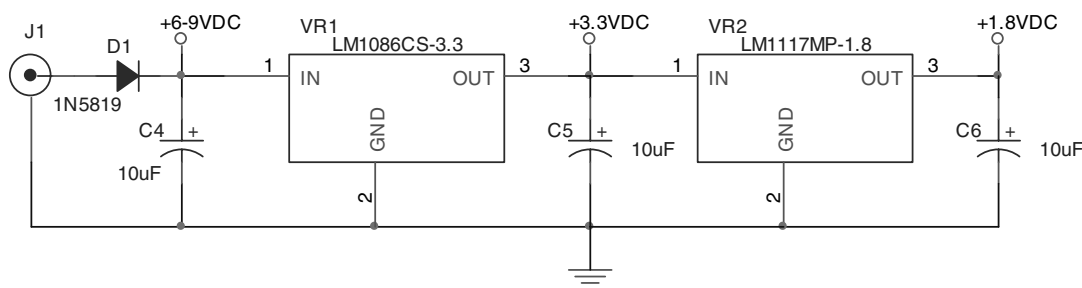
## FOR YOUR INFO

The LPC2106 and LPC2136 adapter boards are available from EDTP Electronics, Inc., at [www.edtp.com](http://www.edtp.com)

### LPC2106 ADAPTER BOARD SCHEMATIC



### LPC2106 SYSTEM POWER SUPPLY



■ **SCHEMATIC 1.** This is a schematic representation of the LPC2106 adapter board. I've thrown in a view of the power supply circuitry we would need to build up to power the LPC2106.

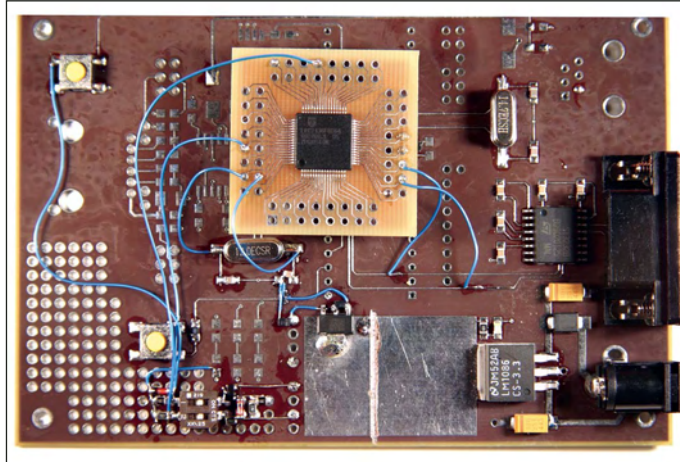


power input pin for the LPC2136, but there is an analog-to-digital converter voltage reference pin ( $V_{ref}$ ), which is filtered with C5, a 10  $\mu$ F tantalum capacitor. A single ground and one power line feed all of the LPC2136 power points. A separate power source must be provided if you don't want to place the voltage reference pin ( $V_{ref}$ ) at the +3.3 VDC level.

It would be redundant to build up both an LPC2106 and an LPC2136 system, as many of the base features of the devices overlap. So, rather than build up a LPC2106 system, I decided that it would be better to build up an LPC2136 system, as all of the

■ **SCHEMATIC 2.** The RS-232 serial port circuitry and the LPC2000 Flash Utility interface circuitry shown here can be added as-is to the LPC2106 schematic to represent a minimal LPC2106 system. As powerful as the LPC2136 is, this is all you need to get it up and running.

■ **PHOTO 3.** Only eight external connections had to be made to bring the LPC2136 to life. The LPC2000 Flash Utility circuitry is at the bottom left of this shot. The extra crystal and the LM1117MP-1.8 for an LPC2106 are on the prototype board, as well.

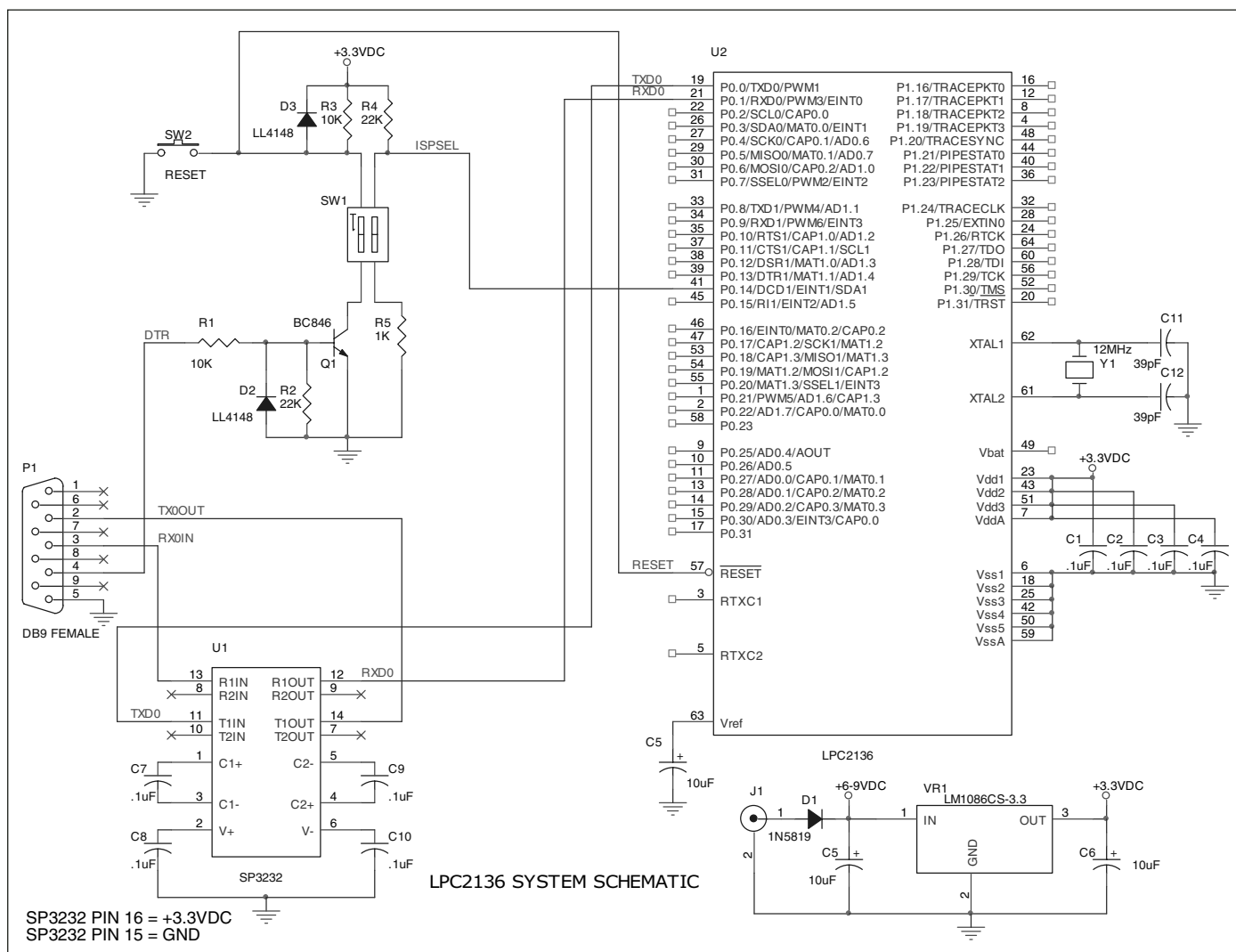


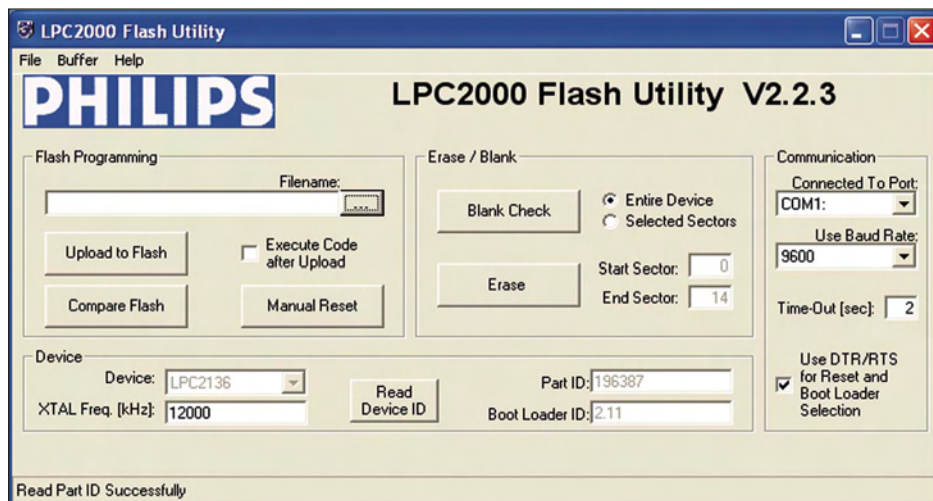
basic ARM7 stuff found within the LPC2106 will still be covered, plus I get to talk about and show you things that have to do with the LPC2136 peripheral set. With that, my LPC2136 test bed is shown in Photo 3. Let's take a look at the hardware you see in Photo 3 subsystem by subsystem, beginning

with the power supply.

## LPC2136 HARDWARE

You can use your favorite brand or type of voltage regulator. All that matters is that you end up with clean,





■ PHOTO 4. Note that I checked the Use DTR/RTS for Reset and Boot Loader box. I clicked on the Read Device ID button and the LPC2136 spit out the Part ID and Boot Loader ID numbers. At this point, I can do everything you see in the window. The Buffer pulldown menu lets you examine the contents of Flash and SRAM.

regulated power. I used an LM1086CS-3.3 at the center of my +3.3 VDC power source for the LPC2136. As you can see in Photo 3, I partitioned a chunk of the LM1086CS-3.3 heatsink pad to accommodate an LM1117MP-1.8 in the event that an LPC2106 was in use instead of an LPC2136.

The power supply subsystem for the LPC2106 and LPC2136 is one of those redundant items I alluded to earlier. The only difference in the power supply circuitry is the inclusion of the +1.8 VDC voltage regulator and its associated support circuitry. Otherwise, there is no rocket science involved in the

LPC21XX power supply design.

The main oscillator circuitry of the LPC2106 isn't as sophisticated as that of the LPC2136. The LPC2136 can generate precision baud rates without having to depend on the input clock frequency being a frequency multiple that is baud rate friendly.

To get the best performance balance between baud rate generation and speed without engaging the PLL, the LPC2106 will generally be clocked at 14.7456 MHz. On the other hand, the LPC2136 can be clocked at 12 MHz and still provide decent baud rate accuracy across the standard baud rate range. Engaging the LPC2136's PLL with a 12 MHz input

clock will also allow the maximum CPU clock rate of 60 MHz to be attained. Our preliminary LPC2136 design is clocked at 12 MHz.

Thus far, we've made design provisions to power and clock our LPC2136. All we need to add to our design at this point is a serial port and a suitable LPC2136 reset circuit. The serial port circuitry is nothing you haven't seen before. A three-volt version of the venerable MAX232 — the MAX3232 — is at the heart of the LPC2136's RS-232 subsystem.

Right now, we will only connect one set of the MAX3232 drivers to the LPC2136's UART0 transmit and receive pins. Connecting to UART0 instead of UART1 will enable us to communicate with the LPC2136 using a free LPC2000 Flash Utility from Philips. However, to use the LPC2000 Flash Utility to its fullest, we must design and construct an LPC2136 reset circuit that interacts with the LPC2000 Flash Utility while, at the same time, provides a stable reset operation for the LPC2136.

The neat thing about this little circuit we're about to examine is that it can be used for a multitude of LCP2XXX devices including the LPC2106. This is yet another one of those redundant LPC2XXX subsystems. Let's take a look at how it works.

The LPC2000 Flash Utility uses the PC serial port's RTS modem control signal to prepare the target ARM7 device to enter ISP mode following a reset. The personal computer serial port's DTR modem control signal is used to perform the reset operation. Our design will eliminate the need for the RTS signal by manually pulling the LPC2136's P0.14 line low using a voltage divider made up of resistors R4 and R5. Resistor R5 is switched in and out by one-half of DIP switch SW1.

When R5 is switched out of the voltage divider, a logical high level is

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supplied to P0.14, which enables normal operation of the LPC2136 following a reset. With resistor R5 switched into the voltage divider, a logical low level is placed on pin P0.14. The low level on P0.14 causes the LPC2136 to enter ISP mode following a valid reset operation. Using the DIP switch and voltage divider circuitry eliminates the need to clone the DTR circuitry made up of R1, D2, R2, Q1, and R3 to set the required ISP logic level at P0.14.

The RS-232 DTR signal from the PC serial port is fed into the base of Q1 via a voltage divider (R1 and R2) and clamp (D2). Diode D2 insures that the maximum reverse emitter-base voltage of Q1 is not exceeded. The reverse emitter-base voltage threshold of Q1 — a Philips BC846 — is six volts.

Some PC serial ports swing between  $\pm 10.0$  volts. Positive voltage swings are tempered to suitable levels by the voltage divider formed by R1 and R2. The negative swings of the DTR line are clamped by diode D2 to  $-0.6$  volts. When the portion of SW1 that is connected to the collector of Q1 is ON, R3 is connected to Q1's collector. The junction of R3 and Q1's collector is connected to the LPC2136's RESET pin.

Thus, when DTR is asserted, Q1 is activated and the junction of R3 and Q1's collector dips to a logical low level, which puts the LPC2136 into reset. Otherwise, DTR is not asserted, Q1 is OFF, and a logical high level is shown to the LPC2136 reset pin. The LPC2000 Flash Utility toggles DTR to alternately activate and deactivate Q1 creating a reset pulse at the LPC2136 reset pin. As you can see, both poles of the DIP switch SW1 must be ON for the LPC2000 Flash Utility to have any effect on the LPC2136.

## FIRE IT UP

Okay, what we have right now is a minimal LPC2136 system. At this point, we should be able to access the LPC2136 using a PC serial port and the LPC2000 Flash Utility, and that's just what I have done in Photo 4. The LPC2136 responded to commands issued by the LPC2000 Flash Utility

and as a result, our preliminary core hardware design is verified.

The LPC2000 Flash Utility allows you to read, write, erase, and blank check the LPC2XXX device at the other end of the serial cable. However, you can't do much useful debugging with it. Next time, we'll add a JTAG interface, finish up the LPC2136 design, and take a look at some tools you can use to code, program, and debug the beast.

In the meantime, I'll make the LPC21XX printed circuit board adapters available to you via the EDTP website at [www.edtp.com](http://www.edtp.com). I'll see you next month and we'll continue on our way to ARMing your Design Cycle. **NV**

## ABOUT THE AUTHOR

■ Peter Best can be contacted via email at [peterbest@cfl.rr.com](mailto:peterbest@cfl.rr.com)

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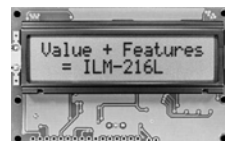
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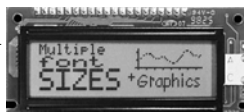
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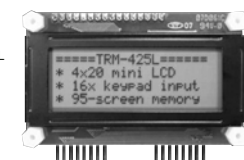
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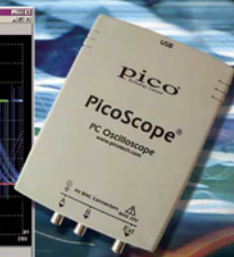
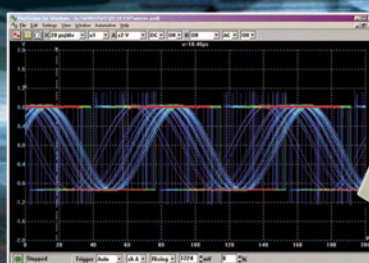
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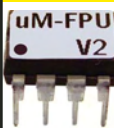
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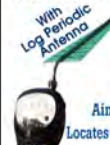
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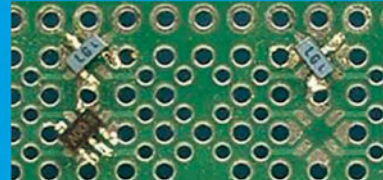


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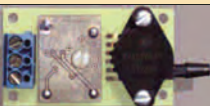
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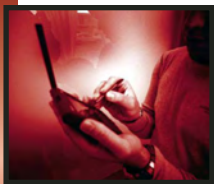
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# READER FEEDBACK

Continued from page 6

column, I state that women have a larger vocabulary for colors than men. This is a fact. I state that women are "more colorful and fashionable than men." This is also a fact. (In birds, the male is usually more colorful; in humans, it's the female.) I suggested that this motivation is transferred to

other things. This is fundamental human psychology. I would encourage Anonymous that some psychology courses or a literature search would be useful. There are differences between men and women. Addressing those differences does not make me "misogynist, prejudicial, and hateful."

It's probably important to know that when I created an engineering department in a large defense contracting company, two of the eight electrical engineers I hired were women. Before that time, out of the dozens of electrical engineers working for the company, NONE were women. And my name is Gerard, not Gerald.

The second point I must address is editorial. Several months ago when I was told that N&V was dropping my column, I realized that they would be publishing critical letters. This is a typical practice to condition the readers for the change. However, I was surprised and disappointed that a reputable magazine such as *Nuts & Volts* would print an anonymous editorial/letter (very different from "name withheld"). This is simply not done (and has not been done for at least the three-plus years that I have been a Contributing Editor). It's inappropriate and unprofessional. Additionally, when such a scathing editorial/letter is going to be published, the accepted form is for the editor to allow the author to respond in the same issue. This is a courtesy to both the readers and the author. Poorly done N&V. Poorly done.

Gerard Fonte

*Critical — as well as complimentary — letters are printed all the time and are in no way an attempt to "condition" the audience for anything. If enough readers are not interested in a topic, it only makes sense to move on. Columns do come and go.*

*Normally, a critical letter would be sent to the writer for comment, but apparently it was overlooked in this case. For that we apologize.*



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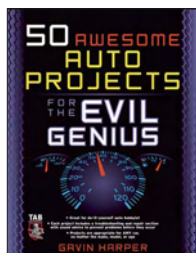
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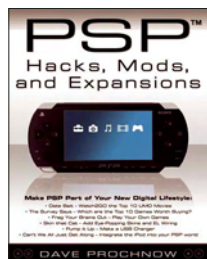


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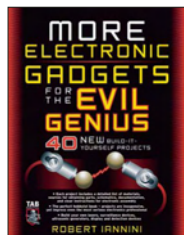
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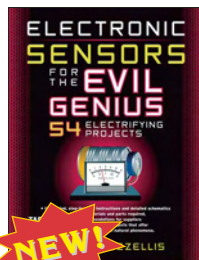
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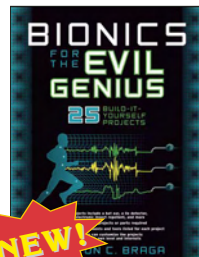
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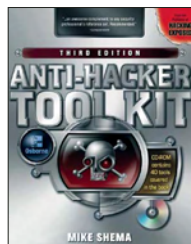


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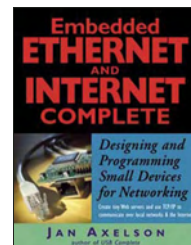
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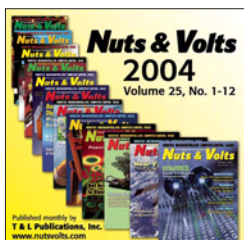
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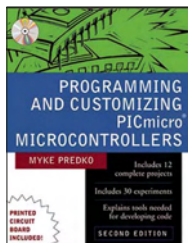


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by Myke Predko

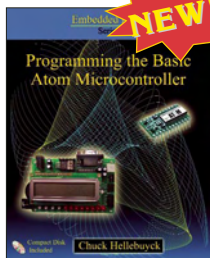
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### Programming and Customizing the PICAXE Microcontroller

by David Lincoln

This beginner-friendly guide from IT pro and PICAXE expert, David Lincoln, shows you just what Revolution Education's PICAXE can do — and helps you make it do it! Packed with ready-to-build projects for all the flavors of PICAXE, the guide provides step-by-step help that's ideal for those just starting out with microcontrollers but also takes more experienced programmers where they need to go fast. Using plenty of examples, *Programming and Customizing the PICAXE Microcontroller* clarifies this versatile chip's basics and coaches you through sophisticated applications. **\$39.95**

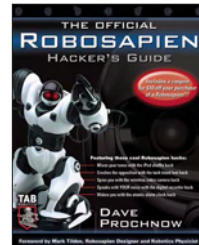


## ROBOTICS

### The Official Robosapien Hacker's Guide

by Dave Prochnow

The Robosapien robot was one of the most popular hobbyist gifts of the 2004 holiday season. The brief manual accompanying the robot covered only basic movements and maneuvers — the robot's real power and potential remain undiscovered by most owners — until now! This is the official Robosapien guide — endorsed by WowWee (the manufacturer) and Mark Tilden (the designer). This timely book covers all the possible design additions, programming possibilities, and "hacks" not found anywhere else. **\$24.95**



### Linux Robotics

by D. Jay Newman

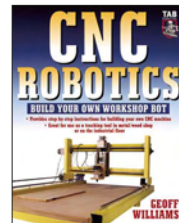
If you want your robot to have more brains than microcontrollers can deliver — if you want a truly intelligent, high-capability robot — everything you need is right here. *Linux Robotics* gives you step-by-step directions for "Zeppo," a super-smart, single-board-powered robot that can be built by any hobbyist. You also get complete instructions for incorporating Linux single boards into your own unique robotic designs. No programming experience is required. This book includes access to all the downloadable programs you need, plus complete training in doing original programming. **\$34.95**



### CNC Robotics

by Geoff Williams

Written by an accomplished workshop bot designer/builder, *CNC Robotics* gives you step-by-step, illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80% of the price of an off-the-shelf bot — and can be customized to suit your purposes exactly because you designed it. **\$34.95**



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# TECH



# FORUM

## This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and **NO GUARANTEES WHATSOEVER** are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to [forum@nutsvolts.com](mailto:forum@nutsvolts.com) All *diagrams* should be computer generated and sent with your submission as an attachment.

### QUESTIONS

To be considered, all questions should relate to one or more of the following:

- ① Circuit Design
- ② Electronic Theory
- ③ Problem Solving
- ④ Other Similar Topics

■ Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).

■ Include your Name, Address, Phone Number, and email. Only your Name, City, and State will be published with the question, but we may need to contact you.

■ No questions will be accepted that offer equipment for sale or equipment wanted to buy.

■ Selected questions will be printed one time on a space available basis.

■ Questions are subject to editing.

### ANSWERS

■ Include in the subject line of your email, the question number that appears directly below the question you are responding to.

■ Payment of \$25.00 will be sent if your answer is printed. Be sure to include your mailing address or we cannot send payment.

■ Only your Name, City, and State, will be printed, unless you say otherwise. If you want your email address included, indicate to that effect.

■ Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

## >>> QUESTIONS

I need some help interfacing the Pocket Watch B with the BASIC Stamp and using the pocket watch to turn some stepper motors at specified times.

**#4061**

**Damian Katz**  
*via Internet*

I recently purchased a Flash card player. The power unit that came with it is an AC to DC supply rated at 5V @ 1.5A. While playing, it actually is using 620mA.

I wanted to connect to 12V automobile power by replacing the AC to DC unit with a 12V to 5V. I measured the amperage and it too was 600mA. The problem now is that the 12V to 5V regulator overheats and eventually will fail. What is going on?

**#4062**

**Emery Pudder**  
*via Internet*

Does anyone have a circuit to convert s-video to composite video (RCA output)?

**#4063**

**Mike Dimatteo**  
*via Internet*

My mother is disabled and can't hear well; one thing she likes to do is go to the mail box. I built a device that signals her from

inside the house when the mail has come, so she does not have to watch for the postal carrier. Now, I want to take it a bit further and connect the device to the TV and have it send both a message and a video flag in one corner while she watches TV. Can someone help or point me to a device that can do this? I would welcome any ideas.

**#4064**

**Anonymous**  
*via Internet*

As a police officer who works one-third of the time on the mid-night shift, I've taken to playing a CD with a single, large file containing pink noise to drown out the daytime noises allowing me a better period of sleep. While it works, the reset noise — as the file is again queued — is annoying. Pink noise seems to work better than white in masking sounds.

Simply detuning a receiver works for white noise, until the taxi cab or bus transmits right outside my house. I'm looking for a way to generate noise, preferably pink noise, without a radio.

**#4065**

**Steve Wolf, W8IZ**  
**North Olmsted, OH**

I would like to hear my TV audio at a remote location through external speakers or earphones.



My TVs have audio outlets in the back, but there is no audio coming out of them.

**#4066** **Edward Juzumas**  
**Grayson, GA**

## >>>> ANSWERS

### **[#2062 - February 2006]**

*I am looking for an easy build-it-yourself receiver to pick up the 60 kHz signal from WWVB. I live in the Pittsburgh, PA area and I have a few atomic clocks that never receive the updates for some reason. I would like to hear or at least see the pulses via an LED indicator just to see if the signal is really there. Any ideas from the forum?*

A Google search for "VLF Radio Receivers" yielded over 300 results. Diagrams, kits, and complete sets were shown. There should be one that will work for you.

**Bob Lindstrom**  
**Broomfield, CO**

### **[#3061 - March 2006]**

*I am plagued with trying to determine when my oil burner ignition transformers have died. These step-up transformers generate 9,300 VAC at about 25 mA (new style electronic types aren't a problem: they die dead). In the old days, I used to test them by shorting a screwdriver across the secondary to see if the sparks came from the screwdriver blade or from broken down insulation on the secondary winding (been knocked off my bucket a few times, but not dead yet!) Then they drop to 6-7 kVAC output, and will not reliably ignite the oil burner (though will still ohm out correctly). Does anyone have a good circuit (read: simple and cheap) that can load these and give me a go/no go reading on their efficacy?*

**#1** If you mounted a Jacob's Ladder on a piece of Lexan, you

could discover how high the spark will travel with a known good transformer, and have a realistic, calibrated tester for less than \$20. By realistic, I mean the Jacob's Ladder will put the suspect transformer to work doing what it was designed to do — create a spark in normal Earth atmosphere. Then you can see a representation of the highest voltage that can be maintained before internal defects betray their presence. You will quickly learn to judge the correct color and sound of the spark, too. I think you should also build a shallow, box shaped cover to keep the Ladder safe from contaminants and mechanically stable while bouncing around in a tool box.

**C. L. Larson**  
**Largo, FL**

**#2** If you have shorted turns in your transformer's high voltage winding, the resistance will read almost as much as a good winding, but the unit will be worthless. The cheapest test would be to turn on the transformer and see if there is a spark at the burner electrodes. No spark = no good. Or, primary amps could be read on a transformer known to be good. Primary amps must be read with the high voltage secondary unloaded by disconnecting it from the burner's spark gap. A bad unit will pull more amps. Don't fool with screwdrivers across the secondary. Besides making your eyeballs become lasers, you could have difficulty staying alive.

**Merv Fulton**  
**Tulare, CA**

### **[#3062 - March 2006]**

*I am currently interfacing my PIC project to several mains relays using an opto-isolated triac (with zero crossing). The current draw required by the mains relay is only 11 mA and the opto-isolated triac is rated at 100 mA. I am currently using the interface and it works perfectly with no heat from the ICs.*

*My question is: Do I need to use zero crossing for relay control? And, I keep hearing about a snubber circuit for inductive loads. Do I really need to use a snubber circuit for just a relay? If so, what would be the simplest design?*

*In the meantime, I will continue to use my interface as it works fine.*

When you switch at the zero crossing, there is no current being stopped so no back EMF to produce a voltage spike and a snubber circuit is not needed. A snubber is needed when you are not switching at a zero crossing. Continue using the interface and don't worry about snubbers.

**Russell Kincaid**  
**Milford, NH**

### **[#3063 - March 2006]**

*I need cross references to standard part numbers for these RadioShack transistors. RadioShack's website was a lost cause.*

NPN, RS2010, Silicon, High Gain, 276-2010  
PNP, RS2034, Silicon, General Purpose, 276-2034  
NPN, RS2042, Silicon, Power, Darlington, 276-2042

I blew the dust off my old RadioShack Semiconductor Cross Reference from 1980, and found all three of your transistors. Generic equivalents are according to the RadioShack cross reference. NTE equivalents are according to their website, found here:

[http://nte01.ntecinc.com/nte/NTERefSemiProd.nsf/\\$\\$Search?OpenForm](http://nte01.ntecinc.com/nte/NTERefSemiProd.nsf/$$Search?OpenForm)

RadioShack # - Generic - NTE #  
RS2010 - PN2484 - NTE123AP  
RS2034 - MPS3906 - NTE159  
RS2042 - 2N6576 - NTE249

Hope this helps. Good luck!

**Walt Anderson**  
**Everett, WA**

Continued from Page 35

## MINIATURE HEAVY-DUTY CONNECTORS



**A** new line of Mini-HMC™ heavy-duty connectors from Molex® Inc., provides up to a 65 percent space savings for applications such as small robots, industrial controls, factory automation, and production and medical equipment. The Mini-HMC system is the first rectangular I/O connector system to offer a similar form and function as traditional heavy duty hard-shell connectors, but in a much smaller size.

Molex adapted and downsized some of the unique features of its existing line of HMC (Heavy Duty Modular) robotics connectors into the Mini-HMC system. A crescent-shaped metal hood with single action lock provides space savings and easy handling, versus double bale-lock types. The "one-touch" spring lock also enables the lever to be smoothly engaged and locked firmly into place.

The Mini-HMC system carries seven amps, which makes it suitable for both signal and power applications. The 3.00mm (.118") modular housings

can be easily inserted and removed from the back-side of the die-cast panel-mount shell without any tools. This provides easier assembly and field-servicing compared to circular versions. Housings can also be placed on the cable hood or panel-mount sides for added design flexibility.

Housings come in modular units of 10 circuits, with a maximum of 40 circuits per side. The Mini-HMC system uses crimp termination, which provides higher reliability and assembly productivity than competitive hand-solder versions. Terminals are gold-plated and available in 18-28 wire gauges.

Plug shells come with protective metal bell-cap assemblies and PVC inserts for cable and dust-debris protection. The Mini-HMC system complies with key industrial standards including VDE 0627/VDE0110, IEC 204-1/IEC 529 (IP65), and UL and CSA.

The Mini-HMC system is part of a broad line of industrial connectors from Molex for robotics and factory automation applications. Pricing for the Mini-HMC system varies. For a typical 40-circuit assembly, pricing is \$45 in quantities of 5,000 pieces.

For more information, contact:  
**Molex Incorporated**  
Web: [www.molex.com/product/mini-hmc.html](http://www.molex.com/product/mini-hmc.html)

## HEAT SHRINK TUBING DISPENSER

**A** new benchtop or wall-mount see-through dispenser that holds five

popular sizes of PVC heat shrink tubing for design, assembly, service, and repair applications is being introduced by Insultab of Woburn, MA.



The Insultab PULL-PAK® Dispenser holds five mini-spools of highly flame retardant, low shrink temperature 1/16", 1/8", 3/16", 1/4", and 3/8" PVC heat shrink tubing; in black or bright colors. A real time saver, it lets users easily see what they need, pull out the exact length, and cut it. Most importantly, the tubing stays in place and won't unravel or pull back.

Featuring a clear canister and sturdy stand, the Insultab PULL-PAK® Dispenser holds 100' of the 1/16" dia. tubing and 25' each of the 1/8", 3/16", 1/4", and 3/8".

The PVC heat shrink tubing has a 2:1 shrink ratio, meets UL-, CSA-, and MIL-specifications, and is RoHS compliant. The dispenser is supplied with black tubing, but a wide variety of bright colors are offered.

The Insultab PULL-PAK® Dispenser is priced from \$129.95 (suggested retail). Literature is available upon request.

For more information, contact:  
**Insultab**  
45 Industrial Pkwy.  
Woburn, MA 01801  
Tel: **781-935-0800**  
Fax: **781-935-0879**  
Web: [www.insultab.com](http://www.insultab.com)

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## AMATEUR RADIO AND TV

Atomic Time .....	34
PolarisUSA Video, Inc. ....	15
Ramsey Electronics, Inc. ....	22-23
Surplus Sales of Nebraska .....	85

## BATTERIES/CHARGERS

Cunard Associates .....	36
-------------------------	----

## BUSINESS OPPORTUNITIES

EZ PCB .....	49
--------------	----

## BUYING ELECTRONIC SURPLUS

GreenChip .....	36
Jaycar Electronics .....	37

## CCD CAMERAS/VIDEO

Circuit Specialists, Inc. ....	106-107
Cosmos .....	99
Matco, Inc. ....	36
PolarisUSA Video, Inc. ....	15
Ramsey Electronics, Inc. ....	22-23

## CIRCUIT BOARDS

Cunard Associates .....	36
ExpressPCB .....	42
EZ PCB .....	49
Manufacturing Consortium, Int'l .....	33
Maxstream .....	14
Micromint .....	93
PCB Cart .....	20
PCB Pool .....	10
Pulsar, Inc. ....	36
R4Systems, Inc. ....	49

## COMPONENTS

Electronics123 .....	98
Front Panel Express LLC .....	33
Jameco .....	31
Lemos International Co., Inc. ....	29
Linx Technologies .....	35
Maxstream .....	14
Micromint .....	93
New Sensor .....	21, 73
Pulsar, Inc. ....	36

## COMPUTER

### Hardware

ActiveWire, Inc. ....	36
COMFILE Technology .....	3
EasySync Ltd. ....	43
Halted Specialties Co. ....	95
National Control Devices, LLC .....	79
Surplus Sales of Nebraska .....	85

### Microcontrollers / I/O Boards

Abacom Technologies .....	49
COMFILE Technology .....	3
Conitec DataSystems .....	59
EMAC, Inc. ....	32
HVV Technologies .....	36

microEngineering Labs .....	98
Micromint .....	93
mikroElektronika .....	72
National Control Devices, LLC .....	79
Net Media.....	2
Parallax, Inc. ....	Back Cover
R4Systems, Inc. ....	49
Scott Edwards Electronics, Inc. ....	94
Texas Instruments .....	7
Trace Systems, Inc. ....	59
World Educational Services .....	66
XGameStation .....	36

## DESIGN/ENGINEERING/REPAIR SERVICES

ExpressPCB .....	42
EZ PCB .....	49
Front Panel Express LLC .....	33
GME Technology .....	36
Manufacturing Consortium, Int'l .....	33
PCB Cart .....	20
PCB Pool .....	10
Pulsar, Inc. ....	36
R4Systems, Inc. ....	49
Trace Systems, Inc. ....	59

## EDUCATION

Atlantic Int'l Institute, Inc. ....	94
Command Productions .....	47
EMAC, Inc. ....	32
Hobby Engineering .....	58
XGameStation .....	36

## ENCLOSURES

Integrated Ideas & Technologies, Inc. ....	32
--	----

## EVENTS

ROBO Business 2006 .....	84
--------------------------	----

## KITS & PLANS

C & S Sales, Inc. ....	78
DesignNotes.com, Inc. ....	30
Electronics123 .....	98
EMAC, Inc. ....	32
Hobby Engineering .....	58
Information Unlimited .....	30
Jaycar Electronics.....	37
QKITS .....	36
RABBIT Semiconductor .....	11
Ramsey Electronics, Inc. ....	22-23
Scott Edwards Electronics, Inc. ....	94
XGameStation .....	36

## LASERS

Information Unlimited .....	30
-----------------------------	----

## MISC./SURPLUS

All Electronics Corp. ....	48
Front Panel Express LLC .....	33
GreenChip .....	36
Halted Specialties Co. ....	95
MCM .....	33
Surplus Sales of Nebraska .....	85

## MOTORS

Jameco .....	31
--------------	----

## PROGRAMMERS

Conitec DataSystems .....	59
---------------------------	----

Electronics123 .....	98
microEngineering Labs .....	98
mikroElektronika .....	72

## PUBLICATIONS

High Voltage Press .....	30
Mouser Electronics .....	29

## RF TRANSMITTERS/RECEIVERS

Abacom Technologies .....	49
Linx Technologies .....	35
Matco, Inc. ....	36

## ROBOTICS

COMFILE Technology .....	3
CrustCrawler .....	83
Hobby Engineering .....	58
HVV Technologies .....	36
Jameco .....	31
LabJack .....	32
Lemos International Co., Inc. ....	29
Lynxmotion, Inc. ....	85
mikroElektronika .....	72
Net Media .....	2
ROBO Business 2006 .....	84
Robot Power .....	36

## SATELLITE

Lemos International Co., Inc. ....	29
------------------------------------	----

## SECURITY

Cosmos .....	99
Information Unlimited .....	30
Linx Technologies .....	35
Matco, Inc. ....	36
PolarisUSA Video, Inc. ....	15

## TEST EQUIPMENT

C & S Sales, Inc. ....	78
Circuit Specialists, Inc. ....	106-107
Conitec DataSystems .....	59
DesignNotes.com, Inc. ....	30
EasySync Ltd. ....	43
Electronic Design Specialists.....	92
GME Technology .....	36
Jaycar Electronics.....	37
LabJack .....	32
Link Instruments .....	5
Pico Technology Ltd. UK .....	94
Trace Systems, Inc. ....	59

## TOOLS

C & S Sales, Inc. ....	78
GME Technology .....	36

## WIRE, CABLE AND CONNECTORS

DesignNotes.com, Inc. ....	30
Jameco .....	31

## WIRELESS PRODUCTS

National Control Devices, LLC .....	79
-------------------------------------	----

Abacom Technologies .....	49
ActiveWire, Inc. ....	36
All Electronics Corp. ....	48
Atlantic Int'l Institute, Inc. ....	94
Atomic Time .....	34
C & S Sales, Inc. ....	78
Circuit Specialists, Inc. ....	106-107
COMFILE Technology .....	3
Command Productions .....	47
Conitec DataSystems .....	59
Cosmos .....	99
CrustCrawler .....	83
Cunard Associates .....	36
DesignNotes.com, Inc. ....	30
EasySync Ltd. ....	43
Electronic Design Specialists .....	92
Electronics123 .....	98
EMAC, Inc. ....	32
ExpressPCB .....	42
EZ PCB .....	49
Front Panel Express LLC .....	33
GME Technology .....	36
GreenChip .....	36
Halted Specialties Co. ....	95
High Voltage Press .....	30
Hobby Engineering.....	58
HVV Technologies .....	36
Information Unlimited .....	30
Integrated Ideas & Tech. ....	32
Jameco.....	31
Jaycar Electronics .....	37
LabJack.....	32
Lemos International Co., Inc. ....	29
Link Instruments .....	5
Linx Technologies .....	35
Lynxmotion, Inc. ....	85
Manufacturing Consortium, Int'l .....	33
Matco, Inc. ....	36
Maxstream .....	14
MCM .....	33
microEngineering Labs .....	98
Micromint .....	93
mikroElektronika .....	72
Mouser Electronics .....	29
National Control Devices, LLC .....	79
Net Media.....	2
New Sensor.....	21, 73
Parallax, Inc. ....	Back Cover
PCB Cart .....	20
PCB Pool .....	10
Pico Technology Ltd. UK.....	94
PolarisUSA Video, Inc. ....	15
Pulsar, Inc. ....	36
QKITS .....	36
R4Systems, Inc. ....	49
RABBIT Semiconductor .....	11
Ramsey Electronics, Inc. ....	22-23
ROBO Business 2006 .....	84
Robot Power .....	36
Scott Edwards Electronics, Inc. ....	94
Surplus Sales of Nebraska .....	85
Texas Instruments .....	7
Trace Systems, Inc. ....	59
World Educational Services .....	66
XGameStation .....	36

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Model	CSI3710A	CSI3711A
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Input Current	0-30A DC	0-30A DC
Input Power	0-150W	0-300W

**CSI3710A: \$349.00**

**CSI3711A: \$499.00**

## 2 Amp Multi-Output Power Supply

This unit is switchable and provides regulated outputs of 3V, 4.5V, 6V, 7.5V, 9V & 12V. All outputs provide 2 Amps of power. Fuse protected. Grey plastic enclosure with on/off switch & red & black output jacks.



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Details at Web Site

> Batteries & Accessories > NiMH Batteries

## Triple Output Bench Power Supplies

with Large LCD Displays

Output: 0-30VDC x 2 @ 3 or 5 Amps  
& 1ea. fixed output @ 5VDC@3A  
Source Effect:  $5 \times 10^{-4} = 2mV$   
Load Effect:  $5 \times 10^{-4} = 2mV$   
Ripple Coefficient:  $< 250uV$   
Stepped Current: 30mA +/- 1mA  
Input Voltage: 110VAC



**CSI3003X3: 0-30VDCx2 @3A \$179.00 5+: \$169.00**

**CSI3005XIII: 0-30VDCx2 @5A \$219.00 5+: \$209.00**

Details at Web Site > Test Equipment > Power Supplies

**NEW!**



**ESD Safe CPU Controlled SMD Hot Air Rework Station**

The heater and air control system are built-in and adjusted by the simple touch of the front keypad for precise settings. Temperature range is from 100°C to 480°C / 212°F to 896°F, and the entire unit will enter a temperature drop state after 15 minutes of non-use for safety and to eliminate excessive wear.



**Only  
\$199.00!**

- CPU Controlled
- Built-in Vacuum System
- Temperature Range: 100°C to 480°C / 212°F to 896°F
- 15-Minute Stand-By temperature "sleep" mode
- Power: 110/120 VAC, 320 W maximum

**Item# CSI825A++**

[Details at Web Site](#) > [Soldering Equipment & Supplies](#)

**Protek 2.9GHz RF Field Strength Analyzer**

The **3290** is a high quality hand-held RF Field Strength Analyzer with wide band reception ranging from 100kHz to 2900MHz. The 3290 is a compact & lightweight portable analyzer & is a must for RF Technicians. Ideal for testing, installing & maintenance of Mobile Telephone Comm systems, Cellular Phones, Cordless phones, paging systems, cable & Satellite TV as well as antenna installations. May also be used to locate hidden cameras using RF transmissions.



**Item# 3290**

[Details at Web Site](#) > [Test Equipment](#) > [RF Test Equipment](#)

**Fantastic Low  
Price:  
\$1899.00!**

- WFM/NFM/AM/SSB modulated signals may be measured.
- Signal Levels up to 160 Channels can be displayed simultaneously on the LCD
- PLL tuning system for precise frequency measurement and tuning
- Built-in Frequency Counter
- LED Backlight LCD (192x192 dots)
- All functions are menu selected.
- RS232C with software for PC & printer interface
- Built-in speaker

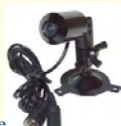
**(Includes Antenna)**

**B&W Pinhole Bullet Camera w/ 1/3" CCD**

- Weather Resistant Housing
- Signal System: EIA
- Image Sensor: 1/3" CCD Bullet Hole
- Effective Pixels: 510 x 492
- Horizontal Resolution: 380TV lines
- Min. Illumination: 1Lux/F1.2

**Item# VC-305CP**

**SALE  
\$39.00**

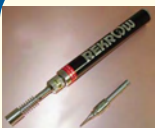


[Details at Web Site](#)

> [Miniature Cameras \(Board, Bullet, Mini's, B/W, Color\)](#)

**Butane Portable Soldering Iron & Kit**

**NEW!**



- Electronic Instant Ignition System
- Naked Flame Burner: Temp to 1300°C/2370°F
- Flameless Burner: up to 400°C/750°F

Two-Piece Iron comes with Solder Tip.

**RK3212: Solder Iron  
\$14.95**

- Equipped with U.S. CPSC Approval Child Safety Standard
- Electronic Instant Ignition System
- Naked Flame Welding: Temp to 1300°C/2370°F
- Soldering Temp: up to 500°C/930°F
- Heat Shrinking: up to 500°C/930°F
- Hot cutting of plastic sheets or plates



**RK3124: Solder Kit  
\$34.00**

[Details at Web Site](#) > [Soldering Equipment & Supplies](#) > [Soldering Irons](#)

**Digital Storage Oscilloscope Module**

PC based Digital Storage Oscilloscope, 200MHz 5GS/s equiv. sampling USB interface

Convert any PC with USB interface to a high performance Digital Storage Oscilloscope. This is a sophisticated PC based scope adaptor providing performance compatible to mid/high level stand alone products costing much more! Comes with two probes.

[Details & Software  
Download at Web Site](#)

> [Test Equipment](#) > [Oscilloscopes/Outstanding Prices](#)

**Price  
Breakthrough!**

**Item# 200DSO Only \$749.00**

**Protek 20MHz Dual Trace Oscilloscope**

- 20MHz Bandwidth
- Alt-Mag sweep for simultaneous display of main and X5 magnified trace
- 1mV/Div Vertical sensitivity
- Alternate trigger for a stable display of unrelated signals
- Multi-level trigger
- X5 Sweep Magnification



**Item# PROTEK 6502**

[Details at Web Site](#)

> [Test Equipment](#) > [Oscilloscopes/Outstanding prices](#)

**\$279.00!**

**Protek 2MHz Sweep Function Generator**

- 0.02Hz-2MHz (7 Ranges)
- Sine, Triangle, Square, Pulse, Ramp, Slew Sine Waveform
- Sync. Out (TTL Square Waveform)
- Accuracy:  $\pm 5\%$  of Full Scale to 200KHz,  $\pm 8\%$  of Full Scale from 200KHz-2MHz
- Sweep Function
- VCG Input



**Item# PROTEK 9205**

[Details at Web Site](#)

> [Test Equipment](#) > [Function Generators](#)

**Special  
\$179.00!**

**SONY Super HAD CCD Color Weatherproof IR Cameras**

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 480TV lines
- Min. Illumination: 0Lux

**Item# VC-827D 1-4: \$149.00 5+: \$139.00**

**SONY Super HAD CCD B/W Weatherproof IR Camera**

- Day & Night Auto Switch
- Signal System: EIA
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

**Item# VC-317D 1-4: \$69.00 5+: \$65.00**

**SONY Super HAD CCD™ equipped camera's feature dramatically improved light sensitivity****SONY Super HAD CCD Color Camera**

- Weather Proof
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 1Lux/F1.2

**Item# VC-805 1-4: \$69.00 5+: \$65.00**

[Details at Web Site](#)

> [Miniature Cameras \(Board, Bullet, Mini's, B/W, Color\)](#)

**SONY Super HAD CCD Color Weatherproof IR Camera**

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

**Item# VC-819D  
1-4: \$89.00 5+: \$79.00**

**SONY Super HAD CCD Mini B/W Board Camera**

- Signal System: EIA
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 420TV Lines
- Min. Illumination: .05Lux/F1.2

**Item# VC-103 1-4: \$33.00 5+: \$29.00**



Visit our website for a complete listing of our offers. We have over 8,000 electronic items on line @ [www.CircuitSpecialists.com](http://www.CircuitSpecialists.com). PC based data acquisition, industrial computers, loads of test equipment, optics, I.C.'s, transistors, diodes, resistors, potentiometers, motion control products, capacitors, miniature observation cameras, panel meters, chemicals for electronics, do it yourself printed circuit supplies for PCB fabrication, educational D.I.Y. kits, cooling fans, heat shrink, cable ties & other wire handling items, hand tools for electronics, breadboards, trainers, programmers & much much more! **Some Deals you won't believe!**

**Circuit Specialists, Inc. 220 S. Country Club Dr., Mesa, AZ 85210**

800-528-1417 / 480-464-2485 / FAX: 480-464-5824



# Parallax RF Modules

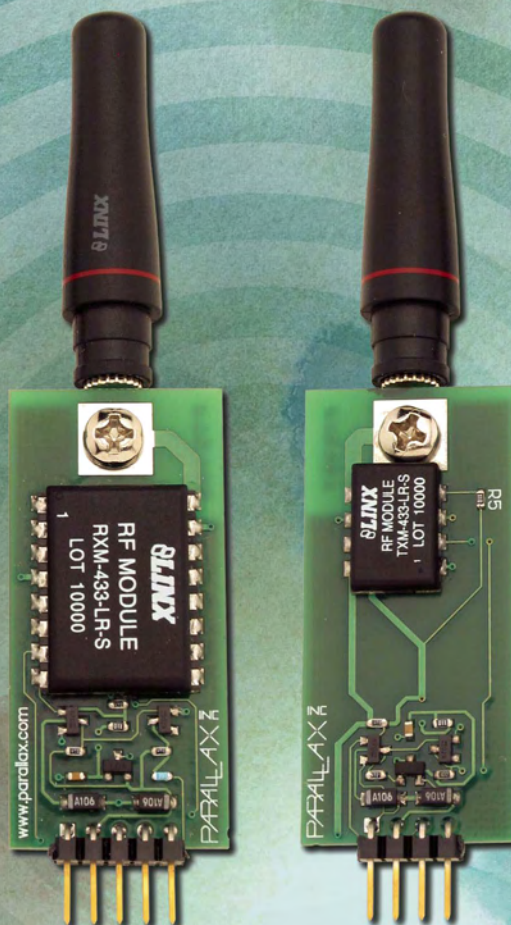
Parallax has produced our own RF modules from products made by the wireless module leader, Linx Technologies. The Parallax RF modules provide a very easy and low-cost method of sending data between microcontrollers or to a PC from 500 ft+ line-of-sight (depending on conditions). Both units have a power down feature and the receiver has a RSSI signal for strength indication.

433 MHz RF TRANSMITTER	#27980	\$29.00
433 MHz RF RECEIVER	#27981	\$39.00

## SPECIFICATIONS INCLUDE:

PCB Size:	0.85" X 1.85" (without antenna)
Overall Size:	0.55" X 3.5" (with antenna)
Power:	5 V +/- 10%
Current:	10 mA
Data rate:	10,000 bps, or 4800 baud
Frequency:	433 Mhz
Transmission:	500 feet+, based on environmental conditions

Order online at [www.parallax.com](http://www.parallax.com) 24-hours  
or call the Parallax Sales Department toll-free  
at 888-512-1024 (Mon-Fri, 7 am-5 pm, PT).



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[www.parallax.com](http://www.parallax.com)

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Take part in Parallax  
workshops at the  
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April 22-23, 2006